NAVELEX 0101,105

NAVAL SHORE ELECTRONICS CRITERIA

SATELLITE COMMUNICATION SYSTEMS

DEPARTMENT OF THE NAVY
NAVAL ELECTRONIC SYSTEMS COMMAND
WASHINGTON, D.C. 20360

JUNE 1970

LIST OF EFFECTIVE PAGES

Total number of pages in this manual is 73 consisting of the following:

Page Number	Effective Date
Title	June 1970
A, B	June 1970
Foreword	June 1970
i through iii	June 1970
1-1 through 1-8	June 1970
2-1 through 2-23	June 1970
3-1 through 3-19	June 1970
A-1 through A-5	June 1970
B-1 through B-5	June 1970
C-1 through C-2	June 1970
FO 3-1 through FO 3-4	June 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.25

RECORD OF CHANGES

CHANGE NO.	DATE	TITLE OR BRIEF DESCRIPTION	ENTERED BY

FOREWORD

The purpose of this book is twofold: to present general indoctrinational information for those unfamiliar with the field of satellite communications and to provide general technical installation criteria for Field Technical Authority representatives.

Although "television via satellite" is familiar to everyone, a knowledge of some of the basic fundamentals of satellite communication systems may prove helpful to those involved in planning for and technically supervising the installation of the earth terminal components of specific satellite communication systems.

All of the present and planned military operational satellite communication systems are sponsored by the Department of Defense and, as such, are designed for tri-service use. The Secretary of Defense assigned responsibility for procurement of all land-based earth terminals to the Department of the Army. All land-based terminals are designed to be mobile and air-transportable, and are housed either in vans or shelters.

The technical installation criteria included in this book are necessarily general. A Department of Defense policy precludes removal of earth terminal equipments from the original vans or shelters so that the terminals will be maintained in a transportable condition. Within the above policy limitations, Department of the Navy policy prescribes semipermanent installation of all Navy-operated terminals.

No attempt has been made in this book to establish complete installation criteria for any particular earth terminal. A separate Base Electronic System Engineering Plan (BESEP) for each installation should be prepared and submitted for approval. This plan should be prepared using the general criteria contained in this book and detailed information given in specific equipment technical manuals, with due consideration of the expected environmental conditions of the local site.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF FOLDOUTS

CHAPTER 1

INTRODUCTION

This chapter presents general background information for those who are unfamiliar with the field of satellite communications. Fundamental features are discussed in this chapter with more detailed treatment reserved for the following chapter.

1.1 WHY SATELLITE COMMUNICATIONS

Communication via satellite is a natural outgrowth of modern technology and the continuing demand for greater capacity and higher quality communications. Relatively recent technical developments have made satellite communications possible. The pressure of near saturation usage of conventional transmission media has caused this new capability to be eagerly sought.

Although the communications facilities of the various military departments have generally been able to support their requirements in the past, predictable requirements indicate that large-scale improvements will have to be made to satisfy future needs of the Department of Defense. The usage rate of both commercial and military systems has increased by at least ten percent per year over the past fifteen years, and there appears to be general agreement that this trend will continue at an accelerated rate. Centralized control of military operations, with its accompanying reliability and security requirements, has generated demands for communications with greater capacity and for long-haul communications to previously inaccessible areas. Some of these requirements can be met only by sophisticated modulation techniques and wide-band, long-distance transmissions for which satellite communication is the most promising means.

1.2 SIMPLIFIED DESCRIPTION

A satellite communication system is one that uses earth-orbiting vehicles, or satellites, to relay radio transmissions between earth terminals. There are two types of communication satellites: active and passive. A passive satellite merely reflects radio signals back to earth. An active satellite, on the other hand, acts as a repeater; it amplifies signals received and then re-transmits them back to earth. This increases the signal strength at the receiving terminal compared to that available from a passive satellite.

A typical operational link involves an active satellite and two earth terminals. One station transmits to the satellite on a frequency called the up-link frequency; the satellite amplifies the signal, translates it to the down-link frequency, and then transmits it back to earth where the signal is picked up by the receiving terminal. This basic concept is illustrated by figure 1-1.

The basic design of a satellite communication system depends to a great degree upon the parameters of the satellite's orbit. By convention an orbit is identified by its

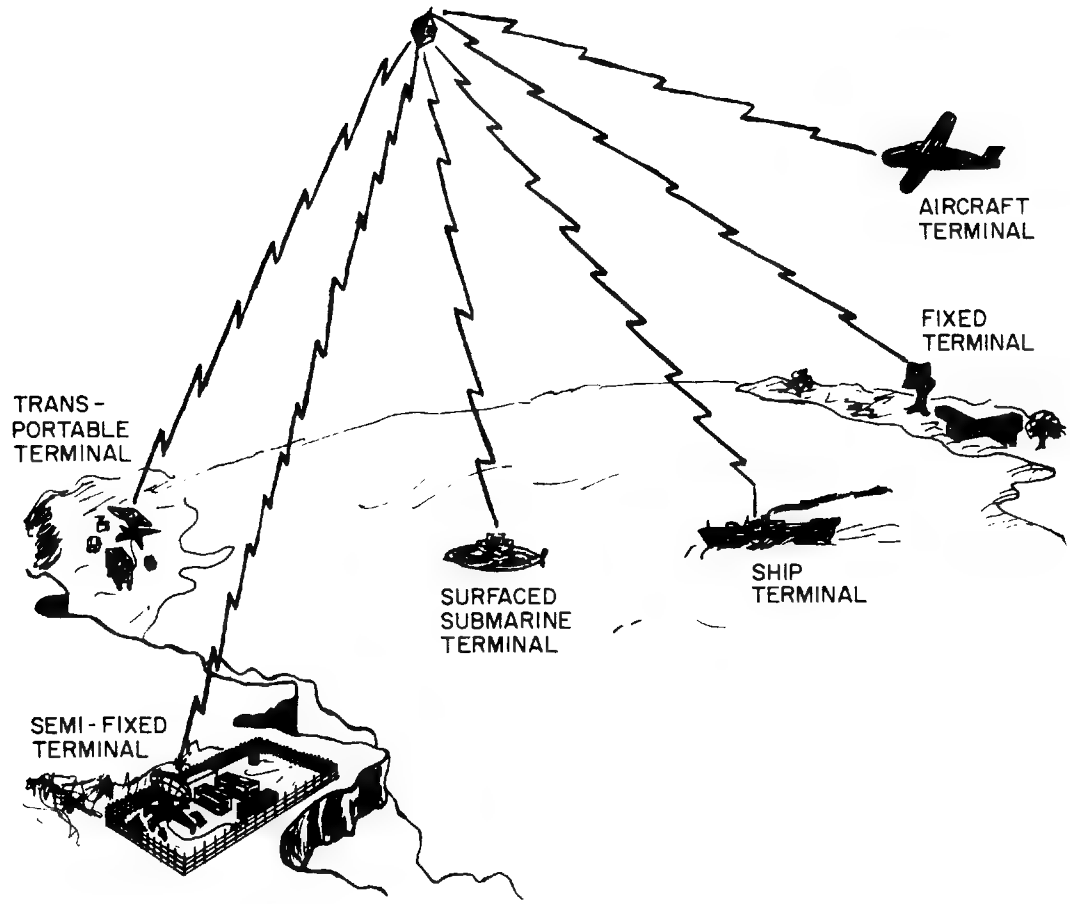


Figure 1-1. Satellite Communication System

shape and the inclination of its orbital plane in relation to the earth's equatorial plane. In general terms an orbit is either elliptical or circular and its inclination is classified as inclined, polar or equatorial. A special type of orbit is a synchronous orbit, one in which the period of the orbit is the same as that of the earth. An orbit which is not synchronous is called asynchronous, with a further subidentification of a near synchronous type in which the period of orbit approaches that of the earth. Orbits are discussed further in section 2.2.

1.3 THE ROLE OF SATELLITE COMMUNICATIONS

In the context of a global military communications network, satellite communication systems become subsystems adding sorely needed capacity or additional alternate routing for communications traffic. A satellite link is just one of several kinds of long-distance links that interconnect switching centers located strategically around the world to comprise the Defense Communications System (DCS) network. Satellite links are usually in parallel with links that employ the more conventional means of communication — HF radio, tropospheric scatter, ionospheric scatter, line-of-sight, microwave, and landline. Satellite links provide added capacity between various points in the network; and, since these links continue in operation under conditions that render other media inoperable, they make a significant contribution to the improvement of reliability.

The primary purpose of the DCS is to provide long-haul, point-to-point communications capabilities to Department of Defense users. Users need only establish communications with the nearest switching center to become network subscribers and to have access to the entire system. Beyond the point-to-point communications requirements there are the tactical communications requirements of the individual services. For the Navy, the potential of satellite communications for tactical (non-DCS) service is most encouraging.

1.4 TYPES OF COMMUNICATION SERVICE

The following types of service are within the capability of present satellite communication systems and either are, or will be, available to the Defense Satellite Communications System (DSCS):

a. Wide-band. This service provides the capability for high-speed data and computer-to-computer transmission. It also provides the capability for relaying television and graphics.

b. Secure-Voice. This service provides the capability for secure-voice conferencing. Alternatively, it can transmit data at 50 kbps.

c. Voice/Data (4 kHz). This service provides for non-secure-analog voice, 2400-bps vocoded voice, 2400-bps data or record traffic transmission, or multiplexed teletype channels.

d. Teleprinter. This service can provide 75-baud record traffic.

1.5 TYPICAL APPLICATIONS

In the application of satellite communication resources to military communications, certain typical deployments will exploit to the maximum extent their versatility and capacity. Some such applications are:

a. DCS Long-Distance, Common-User Communication. This type of communication represents the normal employment of the satellite subsystem. This application provides additional high-capacity wide-band trunks for a variety of transmission modes and added flexibility for rerouting traffic.

b. DCS Area Common-User Communication. Area communication supports large concentrations of forces engaged in operations encompassing a discrete remote area. Such service extends high-capacity, long-distance DCS trunks to a high density of potential users engaged in fluid tactical situations.

c. Contingency Operation. In this application the DCS facilities are extended to support a military operation or humanitarian effort. In this connection, the capability of the satellite subsystem can be used to advantage to support rapid deployment and to furnish reliable long-distance trunking service within a minimum time.

d. Command and Control of Widely Deployed Forces. HF communication to elements of widely deployed forces is difficult even under ideal propagation conditions. On the other hand, the capabilities of a satellite subsystem offer rapid, reliable communication between and among mutually supporting theater and fleet commanders.

A satellite subsystem also possesses the necessary flexibility for system reconfiguration without loss of contact during sudden or frequent headquarters displacement.

e. Tactical Communications. With the development of suitable antennas and equipments that can be installed in most types of ships and aircraft, satellite communications will be able to fill the requirements for various tactical communications, such as ship-to-ship, ship-to-aircraft, ship-to-shore-to-ship, and aircraft-to-ship. This type of communications will be more reliable and less subject to detection than methods presently in use.

f. Fleet Broadcast and Ship-to-Shore. Present fleet broadcasts and ship-to-shore communications rely heavily upon HF for communication over extended distances. As with tactical communications, a satellite subsystem will be more reliable and less subject to detection. This will ensure reliable long-range links between major fleet units and naval communication stations ashore and will simultaneously enhance fleet security.

1.6 ADVANTAGES OF SATELLITE COMMUNICATIONS

Satellite communications offer unique advantages over conventional transmission for long-distance service. Satellite links are unaffected by the propagation anomalies that interfere with HF radio, are free from the high attenuation of wire or cable facilities, and are capable of spanning long distances without the numerous intervening repeater stations which are required for line-of-sight or troposcatter links. They can furnish the greater reliability and flexibility of service needed to support a military operation.

1.6.1 Capacity

Although existing commercial satellite communication systems are capable of handling hundreds of voice-frequency channels, the present operational military communication satellite system, the Phase I Initial Defense Satellite Communications System (IDSCS), is limited to less than a dozen voice channels per earth terminal. Four separately assigned channels, each capable of handling eleven voice channels, are available in each IDSCS satellite on both the up link and down link; however, the power limitations of the Phase I satellite on the down link prevents the use of more than two RF channels simultaneously (one full duplex circuit). In the antijam spread-spectrum mode an RF bandwidth of 40 MHz is used. The Phase II DSCS satellites, now under contract, will have considerably greater channel capability with a considerably wider RF bandwidth.

1.6.2 Reliability

Since propagation of communication satellite frequencies is not dependent upon reflection or refraction and is affected only slightly by atmospheric phenomena, the reliability of active satellite communication systems is limited, essentially, only by the reliability of the equipment employed and the skill of the operating and maintenance personnel. This improvement in reliability is a remarkable advantage for Navy communications, so long dependent upon unreliable HF propagation for most tactical communications.

1.6.3 Vulnerability

Within the present state of the art in rocketry, destruction of an orbiting vehicle is possible; however, destruction of a single communication satellite would be quite difficult and expensive. The cost would be exorbitant compared to the tactical advantage gained. It would be particularly difficult to destroy an entire multiple-satellite system such as the twenty-six random-orbit satellite system currently in use in the IDSCS. The earth terminals offer a more attractive target for physical destruction, but they can be protected by the same measures that are taken to protect other vital installations.

A high degree of invulnerability to jamming is afforded by the highly directional antennas at the earth terminals and by the wide bandwidth system which can accommodate sophisticated antijam modulation techniques such as spread spectrum and frequency hopping.

1.6.4 Flexibility

Almost all of the existing operational military satellite earth terminals are housed in transportable vans that can be loaded into large cargo planes and flown to remote areas. With trained crews these terminals can be put into operation in a matter of hours. Therefore, direct long-haul communications can be established quickly to remote areas nearly anywhere in the free world. (The present and proposed DSCS satellites provide slight coverage in the polar regions at latitudes greater than 70 degrees.)

1.7 LIMITATIONS

Limitations of a satellite communications system are determined by the satellite's technical characteristics and its orbital parameters. Active communication satellite systems are limited by satellite transmitter power on the down links and to a lesser extent by satellite receiver sensitivity on the up links. Early communication satellites have also been limited by low gain antennas.

1.7.1 Satellite Transmitter Power Limitations

The amount of power available in an active satellite is limited by the weight restrictions imposed on the satellite. Early communication satellites were limited to a few hundred pounds because of launch-vehicle payload restraints. The only feasible power source consistent with the above weight limitation is the inefficient solar cell. (Total power generation in the Phase I IDSCS satellites is less than 50 watts.) Thus the RF power output is severely limited and a relatively weak signal is transmitted by the satellite on the down link. The weak transmitted signal, further diminished by propagation losses, results in a very weak signal being available at the earth terminals. The level of signals received from a satellite is comparable to the combination of external atmospheric noise and internal noise of standard receivers. Consequently, special techniques must be used to permit extraction of the desired communication information from the received signal. Large, high gain antennas and special types of preamplifiers solve this problem but add complexity and size to the earth terminal. (The smallest terminal in the IDSCS has an 18-foot antenna and weighs 19, 500 pounds.) Development of more efficient power sources and relaxation of weight restrictions will permit improved satellite performance and increased capacity.

1.7.2 Satellite Receiver Sensitivity

Although powerful transmitters and highly directional antennas can be used at an earth station, the spherical wavefront of the radiated signal spreads as it travels through space. The satellite antenna intercepts only a small amount of the transmitted signal power and, because of its low gain, a relatively weak signal is received at the satellite receiver. Although the strength of the signal received on the up link is not as critical as that received on the down link, careful design of the RF stage of satellite receivers is required to achieve satisfactory operations. Development of stabilized high gain antennas and improved RF input stages in the receiver will make this problem less critical.

1.7.3 Satellite Availability

The availability of a satellite to act as a relay station between two earth terminals depends on the locations of the earth terminals and the orbital parameters of the satellite. All satellites, except those in a synchronous orbit, will be in view of any given pair of earth stations only part of the time. The length of time that a nonsynchronous satellite in a circular orbit will be in the zone of mutual visibility depends upon the height at which the satellite is circling. Elliptical orbits cause the satellite zone of mutual visibility between any two earth terminals to vary from orbit to orbit, but the times of mutual visibility are predictable. See figure 1-2 for an illustration of the zone of mutual visibility.

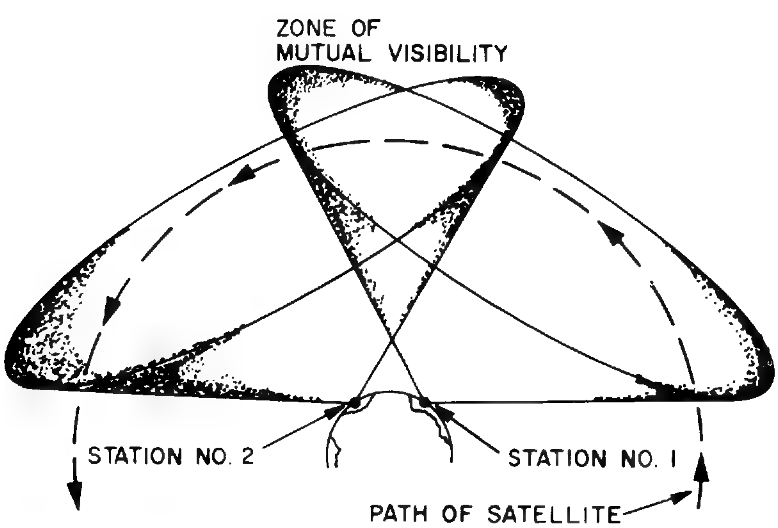


Figure 1-2. Zone of Mutual Visibility

1.8 SATELLITE PROJECTS

The tremendous potential of satellite communications has long been realized. As early as October 1945, long before the Russian SPUTNIK of October 1957, Arthur C. Clarke, a former chairman of the British Interplanetary Society, writing in Wireless World, discussed the potential of synchronous satellite communications.

The first successful satellite communications utilized the earth's natural satellite, the moon. In November 1955, almost two years before SPUTNIK was launched, the moon was used as a passive satellite to establish a teletype link between Washington, D. C. and Hawaii. Later, in 1960, successful communications were conducted with an artificial passive satellite, ECHO. This was a large, highly reflective, inflated balloon which had been injected into a near circular inclined orbit about 1000 miles high with an inclination of 47 degrees.

SCORE, launched in December 1958, was the first active communication satellite. SCORE was injected into an inclined elliptical orbit and broadcast for thirteen days President Eisenhower's recorded Christmas message. TELSTAR 1 was launched into an inclined elliptical orbit in July 1962 and became the first high-capacity communication satellite.

All of the above communication satellites advanced the state of the art, but all were of limited usefulness because their orbital geometry made them visible to earth terminals only part of the time. The state of the art in rocketry had not advanced sufficiently to permit injection of a satellite into a synchronous equatorial orbit. In such an orbit the satellite would appear motionless to any earth terminal within the satellite's area of visibility.

1.8.1 SYNCOM Project

Successful injection of a satellite into a quasi-synchronous, nearly circular, inclined orbit occurred with the first SYNCOM satellite, launched in February 1963. Although the communication package of this SYNCOM satellite was destroyed by an explosion that occurred when the satellite was injected into its final orbit, the SYNCOM 1 launch was the first demonstration of a new method to inject a payload into a synchronous orbit.

SYNCOM 2, launched in July 1963, also achieved a quasi-synchronous, near circular, inclined orbit and its communication package operated properly. NASA conducted a number of tests and then turned over the operation of the satellite to the Department of Defense.

SYNCOM 3, launched in August 1964, was injected into a synchronous, circular, equatorial orbit. To an observer on earth, SYNCOM 3 appeared to be suspended and motionless over the equator. After some experimentation with SYNCOM 3, NASA turned over the operation of the satellite to the Department of Defense.

The SYNCOM launches were the forerunners of the commercial EARLY BIRD and INTELSAT communication satellites and the Initial Defense Communications Satellite Program (IDCSP) satellites.

1.8.2 Defense Satellite Communications System (DSCS)

The IDSCS, under the direction of the DCA, consists of twenty-six, equatorially positioned, randomly spaced, near synchronous satellites. These active satellites, which are part of the DSCS, have a limited capacity at the present time. Subsequent phases of this project, when implemented, will produce an increased wide-band digital communication capability by employing satellites with increased power and capacity. The DSCS is presently programmed in three phases:

a. Phase I. - This phase evolved from the use of the SYNCOM and IDCSP satellites. (The SYNCOM satellites have deteriorated and are no longer used.) The Advanced Defense Communication Satellite Project, scheduled to follow the IDCSP, has given way to a more evolutionary phased approach. Subsequent phases will employ synchronous equatorial satellites with increased radiated power and controllable high gain antennas.

b. Phase II. - The primary objective of Phase II is to achieve an enhanced communication capability during the 1971 to 1975 period. The plan is to add synchronous equatorial, station-kept, medium-power satellites to increase system capability. Earth terminals will also be modified in three stages to increase bandwidth and to improve modulation techniques. This, in turn, will increase channel capacity and protect the communication service.

c. Phase III. - During Phase III, the modulation method will be changed, higher powered satellites will be added, and the earth subsystem will be expanded to include airborne and smaller ground terminals. This phase, which should provide greater survivability, flexibility, availability and capacity than Phase II, is planned for implementation during the post-1975 time period. The earth terminals will include second generation equipment, retaining the most desirable features of the Phase II equipment and incorporating subsequent improvements in the state of the art.

1.8.3 TACSATCOM

Supported by data obtained from the Lincoln Experimental Satellite (LES) series of experimental satellites (particularly LES-5 and LES-6), an inter-service developmental Tactical Satellite Communication (TACSATCOM) Program was established under the direction of a steering group composed of Army, Navy, Air Force and Marine Corps representatives. The TACSATCOM satellite, launched in February 1969 into a synchronous equatorial orbit, operates in the UHF and SHF bands. Two similar families of terminal equipments, one using UHF and one using SHF, are designed for a wide spread of tactical uses, ranging from a one-man pack warning and alerting receiver to transceivers for a two- or three-man pack or for jeep mounting or shelter mounting. Airborne, surface ship and submarine terminals are included in the program.

All the transceivers can transmit and receive on at least one voice (or teletype) channel. Other versions can handle up to 6 full duplex voice channels, including some vocoded voice, and the largest version can handle high-speed data through either a differential phase-shift keyer modem or the tactical transmission system (TATS) bandspread multiple frequency modem.

CHAPTER 2

DESCRIPTION OF COMMUNICATION SATELLITE SYSTEM

2.1 ESSENTIAL BASIC SYSTEM COMPONENTS

The essential basic system components of an operational communication satellite system are (1) an orbiting vehicle with a communication receiver and transmitter installed and (2) two earth terminals equipped to transmit signals to and receive signals from the satellite. The design of the overall system determines the complexity of the various components and the manner in which the system operates. The launch and deployment facilities to be used also affect the overall design of the operational system. With the present operational military communication satellite system only two earth terminals can use a satellite at one time, and this has led to the establishment of satellite scheduling or control facilities.

Since the Phase I IDSCS system consists of randomly spaced satellites, the locations of which are changing continuously, a facility for predicting satellite locations is required to provide accurate antenna pointing information.

2.2 ORBIT DESCRIPTIONS AND SELECTION CRITERIA

2.2.1 Types of Orbits

As noted previously in section 1.2, orbits generally are described according to the physical shape of the orbit and the angle of inclination of the plane of the orbit.

a. Physical Shape. All satellites orbit the earth in elliptical orbits that are determined by the initial launch parameters and the later deployment techniques used. (A circle is a special case of an ellipse.) The elliptical path of any satellite has the earth located at one of its foci as shown in figure 2-1.

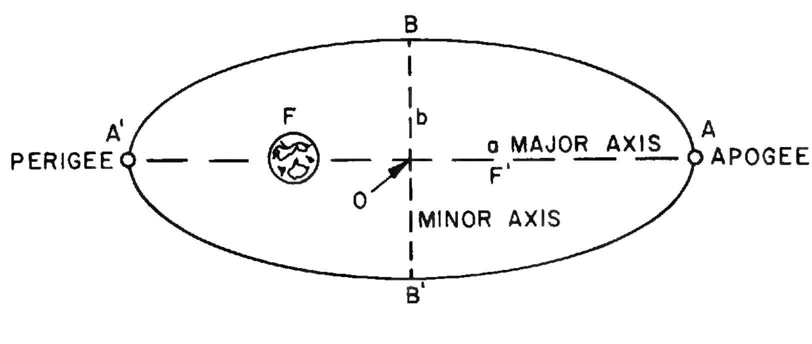


Figure 2-1. Elliptical Satellite Orbit

Perigee and apogee are two of the three parameters customarily used to describe orbital data of a satellite. Perigee is defined as the point in the orbit of a satellite that is nearest to the center of the earth. Apogee is defined as the point in the orbit of a satellite at the greatest distance from the center of the earth. By convention both distances usually are expressed from the surface of the earth in statute miles, although nautical miles usually are used for military systems.

b. Angle of Inclination. The angle of inclination is the third parameter customarily used to describe orbital data of a satellite. Most satellites orbit the earth in orbital planes which are not coincident with the earth's equatorial plane. A satellite orbiting in any plane not coincident with the equatorial plane is in an inclined orbit.

The angle of inclination is the angle between the equatorial plane and the orbital plane as shown in figure 2-2.

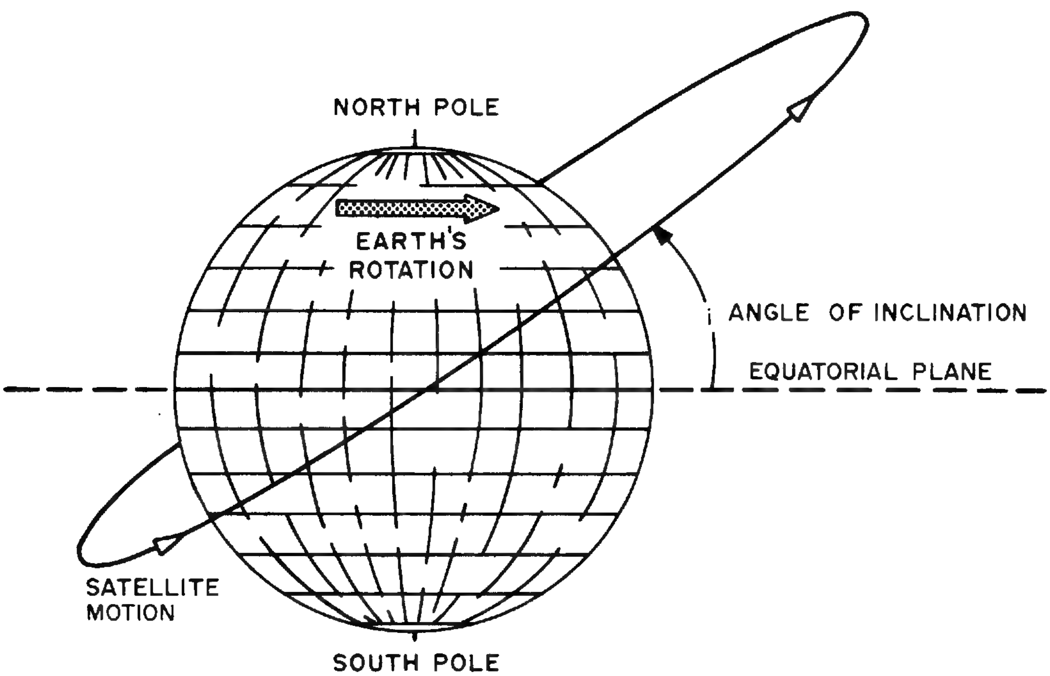


Figure 2-2. Inclined Satellite Orbit

c. Special Types of Inclined Orbits.

(1) Equatorial Orbit. A satellite orbiting in a plane that coincides with the earth's equatorial plane is in an equatorial orbit.

(2) Polar Orbit. A satellite orbiting in an inclined orbit with an angle of inclination of 90 degrees or near 90 degrees is in a polar orbit.

d. Circular Orbits. A circular orbit is a special type of elliptical orbit in which the major and minor axis distances are equal or approximately equal. Mean height above earth, instead of perigee and apogee, is used in describing a circular orbit.

e. Special Types of Circular Orbits.

(1) Synchronous Orbit. A satellite in a circular orbit at a height of approximately 19, 300 nautical miles above the earth is in a synchronous orbit. At this altitude the satellite's period of rotation is 24 hours, the same as the earth's, and the satellite orbits in synchronism with the earth's rotational motion. Although inclined and polar synchronous orbits are possible, the term synchronous, as commonly used now, refers to a synchronous equatorial orbit. In this type of orbit, satellites appear to hover motionlessly in the sky.

(2) Near Synchronous Orbit. A satellite in a circular orbit within a few thousand miles of 19, 300 nautical miles above the earth is in a near synchronous orbit. If the orbit is lower than 19, 300 nautical miles, the satellite's period is less than the earth's and the satellite appears to be moving slowly around the earth from west to east. (This type of orbit is also called sub-synchronous.) If the orbit is higher than 19, 300 nautical miles, the satellite's period is greater than the earth's and the satellite appears to be moving slowly around the earth from east to west. Although inclined and polar near synchronous orbits are possible, common usage of the term near synchronous implies a near synchronous equatorial orbit.

(3) Medium Altitude Orbit. A satellite in a circular orbit from approximately 2000 miles to 12, 000 miles above the earth is considered to be in a medium altitude orbit. The period of a medium altitude satellite is considerably less than that of the earth, causing such satellites to appear to move rather quickly across the sky from west to east.

2.2.2 Factors That Affect Choice of Orbits

The early attempts at communication using artificial satellites were severely limited by the state of the art in rocketry and the choices of orbits were quite limited. Improvements in rocket capabilities, new methods of orbital injection, and development of satellite positioning control have removed the original limitations in the choice of orbits.

a. Coverage Desired. The first factor to be considered in choosing the type of orbit for a communication satellite system is the coverage desired to be provided by the system. The area of coverage depends upon the inclination of the orbit, the shape of the orbit, the height of the orbit, and the number of satellites available in the system.

The inclination of the orbit determines the geographic limits of the projection of the path of the satellite over the earth's surface. The greater the inclination, the greater the amount of the earth's surface that is covered by the satellite. This is shown graphically in figure 2-3.

The area of coverage of a satellite at any particular time depends on the height of the satellite above the earth (and possibly may be restricted due to the antenna pattern of the satellite). If a satellite is in an elliptical orbit the area coverage varies with the position of the satellite in the orbit.

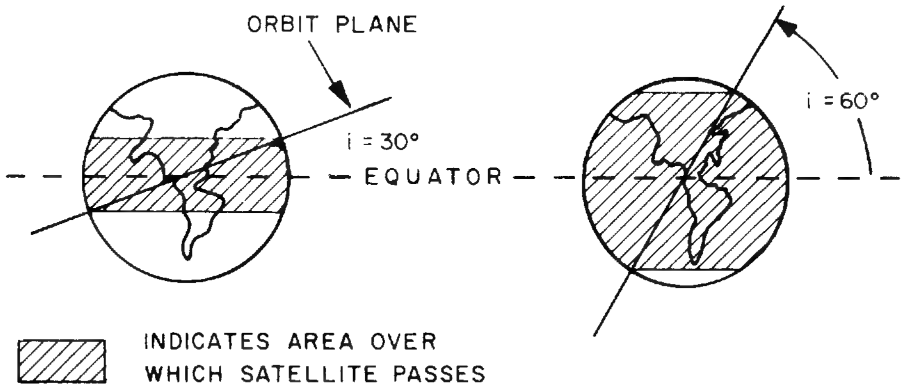


Figure 2-3. Effect of Orbit Plane Inclination on Satellite Coverage

Availability of a satellite at a particular point on the earth's surface varies with the height and shape of the orbit. Availability of a satellite in circular orbit occurs at regular intervals, the frequency of which is determined by the height and inclination of the orbit, whereas the availability of a satellite in elliptical orbit varies in length of time with each passage of the satellite, and the recurrence of availability depends upon the orbital parameters.

All of the above factors must be considered in designing a communication satellite system. Several typical systems are discussed below.

(1) Global Systems. In the design of a global communication satellite system the use of synchronous equatorial satellites is quite advantageous. Figure 2-4 shows how one of these satellites can illuminate almost one-half of the earth's surface.

Three of these satellites can provide coverage over most of the earth's surface (except for the extreme north and south polar regions). A polar projection of the global coverage of such a three-satellite system is shown in figure 2-5.

A disadvantage of such a system is that provisions must be included in the satellites for maneuvering them as necessary to maintain their proper positions (positioning control). Another disadvantage is the length of time that would be required to replace a satellite if one should experience a catastrophic failure.

The Phase II DSCS system design has some special coverage features, but it is basically the same as that shown in figure 2-5.

The Phase I IDSCS communication satellite system, which was designed for continuous global coverage, utilizes a number of satellites in near synchronous equatorial circular orbits. Since the periods of each of these satellites are different, averaging about 22 hours, all of the satellites appear to be moving slowly in a random fashion around the earth from west to east. At least one satellite is available almost continuously for use by adjacent pairs of earth terminals. If a satellite fails, another of the randomly spaced satellites becomes available within an acceptable length of time (without waiting for a replacement launch).

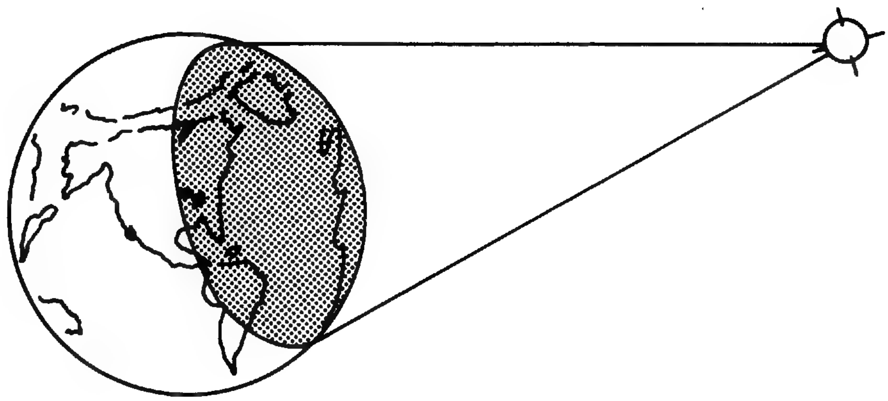


Figure 2-4. Illumination from a Synchronous Satellite

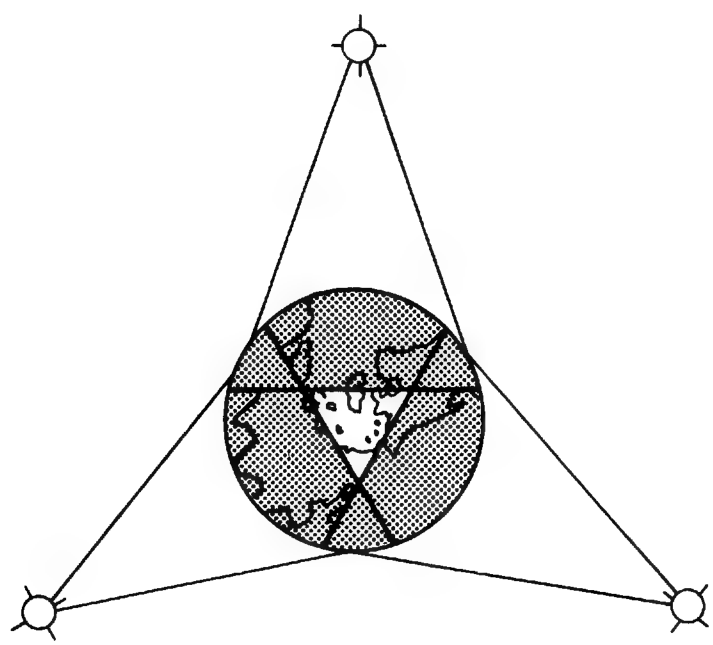


Figure 2-5. Worldwide Synchronous Satellite System Viewed from above North Pole

(2) Northern Hemisphere System. The Russian communication satellite system, which was designed primarily for coverage of the northern hemisphere, utilizes satellites in elliptical orbits with perigees of about 290 statute miles, apogees of about 24, 700 statute miles, and inclinations of about 64°. In this system the satellites are over the northern hemisphere considerably longer than over the southern hemisphere.

b. Effects of Geographic Location of the Launch Pad. Prior to the development of a second start capability in rocket motors, the geographic location of the launch pad determined the minimum inclination of any achievable orbit. Without the technique of dog-legging (described below), the angle of inclination of the orbit cannot be any less than the latitude of the launch site. The reason for this is that the point of injection into orbit is a point on the orbit. Thus, a satellite launched from Cape Kennedy (latitude 28° N.) will return to at least latitude 28° N. and thus the minimum achievable angle of inclination is 28°. To launch an equatorial satellite without using the dog-leg technique, the launch pad would have to be located somewhere along the equator.

After the development of a restart capability in rocket motors, a dog-legging technique was conceived to permit achievement of orbits with inclinations less than the latitude of the launch pad. To obtain less than a 28 degree inclination from Cape Kennedy, an intermediate, or parking, orbit is first required. The intermediate orbit is achieved in the usual fashion. (A due east shot is made from the launching station.) As a result, the inclination angle of the parking orbit will be the latitude of Cape Kennedy — 28 degrees. The thrust of the remaining rocket engine is then applied at right angles to the parking orbit when the satellite and rocket engine are near the equator. In reaction to this thrust, the satellite veers into an orbit of the desired inclination with no change in either altitude or velocity. This is the technique known as dog-legging.

c. Launch Capability Restraints. The size and number of satellites to be launched and the type of orbit desired determine the kind of rocket that is needed to accomplish the launch. The rocket's lift capability must be great enough to carry the payload to its desired orbital injection position and to cause it to have the desired orbital velocity upon injection.

For early launches, in-flight changes were not possible so achievable orbits were limited to those with inclinations equal to or greater than the latitude of the launch site. The development of more sophisticated (controlled multiple burn) rocket motors eliminated the "latitude of launch" restriction; however, more complex and heavier rockets must be used to achieve orbits with inclinations less than the latitude of launch.

A second artificial restraint to early launches was caused by safety precautions. The uncertainties of rocket launching demand, as a matter of public policy, that all rockets contain self-destruct capabilities for use in case of malfunctions and erratic flight paths. The geographic limits of areas where rockets can be safely destroyed severely limit the directions in which rockets can be launched. As rockets developed greater power, the down-range motor-burnout distances became greater, imposing further restrictions on the initial launch directions.

With the rapid development of sophisticated rockets the launch-capability restraints are primarily economic. In the case of military communication satellite systems, technology is available to achieve any chosen orbit; however, budgetary limitations determine the scope of present day operations.

d. Acquisition and Tracking Considerations. In choosing a type of orbit for a satellite communication system, the problems associated with acquisition and tracking of the satellites by the earth terminals must be considered. With elongated elliptical orbits and medium altitude circular orbits the satellites move past the earth terminals at a rapidly changing angular rate; and, searching for and acquiring the particular assigned satellite is a difficult task even though accurate initial antenna pointing information is provided. Contrariwise, with the near synchronous and synchronous orbits the satellites appear to move quite slowly or not at all; and, with proper antenna pointing information, searching for an assigned satellite is quite easy, and tracking is very simple.

With elliptical and medium altitude orbits the satellite transmitted frequencies change depending upon whether the satellite is approaching or receding due to the doppler effect. This also increases the difficulty of acquiring the satellite. In the near synchronous orbits doppler effects are minimized and they are nonexistent with synchronous orbits.

In short, elliptical and medium altitude orbits, which are relatively easy and more economical to achieve, introduce considerabie complexities in the earth terminal acquisition and tracking equipments. The near synchronous and synchronous orbits, which are more difficult and more expensive, require much simpler acquisition and tracking equipment for the earth terminal.

2.3 SATELLITE CHARACTERISTICS

a. Size and Weight Considerations. A prime consideration in determining the size and weight of a satellite is the payload that available rockets can accommodate. Early communication satellites were limited to the diameter of the final stage of the rocket that was to be used for launching. Similarly, the weight was determined by the thrust of the rocket motors and the maximum weight that the rocket could lift into the desired orbit.

As the thrust of rocket motors increased and the rocket diameter increased, size and weight restrictions were eased. The maximum size of a satellite is still limited essentially to the diameter of the final stage of the rocket to be used and the space within the nose fairing. Similarly, the maximum weight of a satellite is limited by the maximum thrust of the rocket motor. However, rockets and rocket motors already developed are so large that these factors are not usually the prime considerations that determine the size and weight of satellites in modern systems. This will be discussed further below.

b. Single or Multiple Launch. As soon as the state of the art in rocketry progressed to the point that relatively large payloads could be lifted into orbit, a technique was developed to permit multiple launches from one rocket. As early as June 1960, two satellites were successfully placed in orbit by the same launch vehicle. With the development of this multi-launch capability, additional flexibility was made available in the design options as to size, weight and number of satellites to be included in each launch. These factors must be considered within the context of the desired system parameters.

The Phase I IDSCS communication satellite system was initially designed to consist of fifteen randomly spaced, near synchronous satellites. When the powerful TITAN IIIC rockets became available to lift the IDCSP satellites into near synchronous equatorial orbits, it was determined that the TITAN IIIC could accommodate within

its fairing a total of eight satellites, each approximately 36 inches in diameter and weighing 100 pounds. The 26 IDCSP satellites were injected into their orbits as the result of four successful multiple launches which included a few other satellites as well.

The Phase II DSCS communication satellite system will have larger and heavier satellites in synchronous equatorial orbits. Present planning indicates that two of these Phase II satellites will be injected into orbit from a single launch. Figure 2-6 is a drawing of the Phase II satellite.

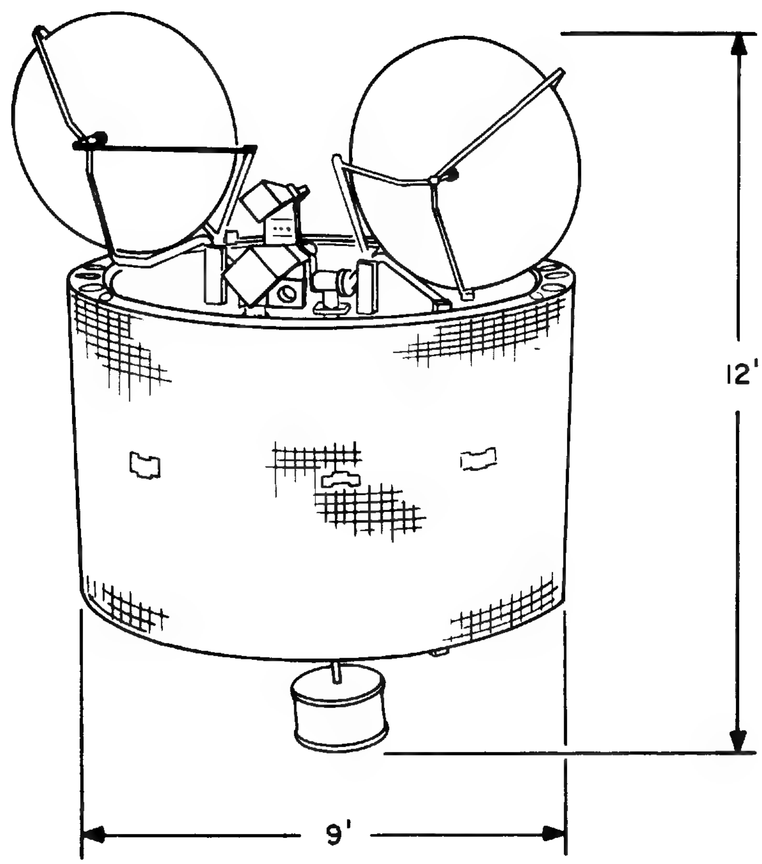


Figure 2-6. Phase II DSCS Satellite

As previously mentioned, early limitations on size and weight of satellites have been removed by advances in technology, and economic considerations have become the primary restraint.

c. Power Sources. Early communication satellites were severely limited by the lack of suitable power sources; this, in turn, severely limited the output power of the satellite transmitter. The only source of power available within early weight restrictions was a very inefficient panel of solar cells without battery backup. A major disadvantage of this type of power source is that the satellite has no power when the satellite is in eclipse. For continuous communications this outage is unacceptable.

A combination of solar cells and storage batteries is a better prime power source for satellites. This is a practical choice at this time, even though the result is far from an ideal power source. Because of the relatively low conversion efficiency of the solar cells, the combination is limited to approximately one watt of deliverable power per pound. About ten percent of the sunlight energy converging on the solar cells is converted to electrical power. Even this low efficiency is further decreased when the solar cells are bombarded by high-energy particles that are sometimes encountered in space.

The IDCSP satellites have over 8500 solar cells mounted on the surface of the satellite. Initially these cells supplied about 42 watts. No battery backup was provided.

The Phase II DSCS satellites will have about 32, 000 solar cells, initially supplying about 520 watts, mounted on the surface of the satellite. A nickel cadmium battery will be used for backup power during eclipses.

Although numerous nuclear power sources have been used in space for special purposes, the state of the art has not progressed sufficiently for nuclear power sources to be competitive with the solar cell-battery combination for synchronous communication satellites. With solar cells exposed to the sun continuously (and battery backup for eclipses), the solar cell-battery installations will be lighter in weight, more efficient and less costly than existing nuclear power sources. This situation may change in the future as power requirements increase above 10 kW and, particularly, if low cost nuclear fuels become available.

d. Satellite Orientation. Satellite orientation in space is quite important for two reasons: continuous solar cell orientation and continuous antenna orientation. Since the primary source of power in most satellites is from solar cells, it is essential that the maximum number of the solar cells be exposed to the sun at all times. Moreover, for useful communications, the satellite antenna must be visible to appropriate earth terminals. Early communication satellites used spin stabilization to meet these important requirements.

Spin stabilization operates on the principle that the direction of the spin axis of a rotating body tends to remain fixed in space. A natural example of spin stabilization is the effect of the earth's rotation in keeping its axis fixed in space. A satellite having a spin axis parallel to the earth's axis will maintain this position since both axes are fixed in space. Figure 2-7 illustrates the use of this principle with an equatorial orbit satellite to keep a doughnut-shaped antenna pattern pointing toward the earth.

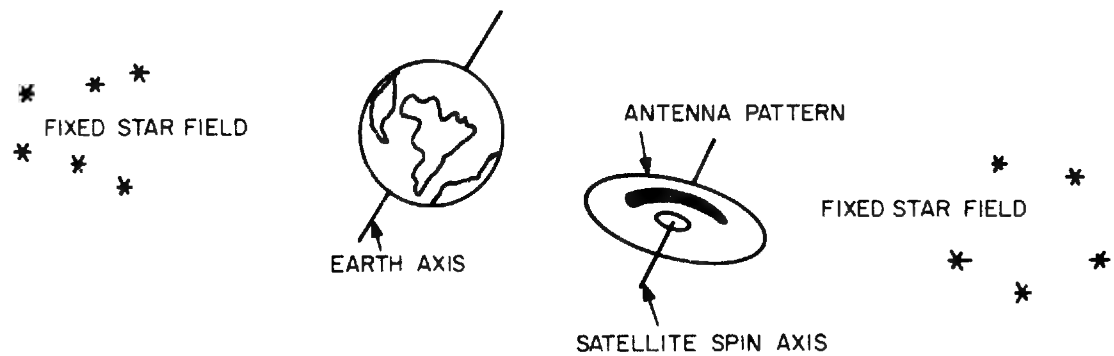


Figure 2-7. Spin-Stabilized Satellite Antenna Pattern

Spin stabilization requires virtually no additional energy or expenditure of mass once the system is in motion. A spin-stabilized satellite is usually constructed like a flywheel with the heavier equipment mounted in the same plane and as close to the periphery as possible. See figure 2-8.

After orbital injection, the radial jets are pulsed to initiate spinning. The satellite spin axis is oriented to the earth's axis by means of the axial jets, which are pulsed at the proper spin phase. The velocity jets, pulsed at the proper spin phase, provide orbit position and velocity correction.

By installing solar cells all around the periphery of the spin-stabilized satellites a large number of solar cells are exposed to the sun at all times (except when the satellite is in eclipse). By installing antennas that radiate in all directions around the spin axis a small part of the total radiated energy is directed toward the earth at all times.

The Phase I IDSCS satellites are spin stabilized, as described above. They utilize solar cells mounted on the periphery of the satellite and have two omnidirectional antennas installed around the spin axis.

In an effort to overcome the disadvantage of omnidirectional antennas, which radiate only a small amount of energy toward the earth, various techniques to achieve an earth-oriented antenna system have been developed and the most promising have been tested in space vehicles. The best system developed to date uses spin stabilization for orientation of the satellite with a despun inner platform for mounting controllable

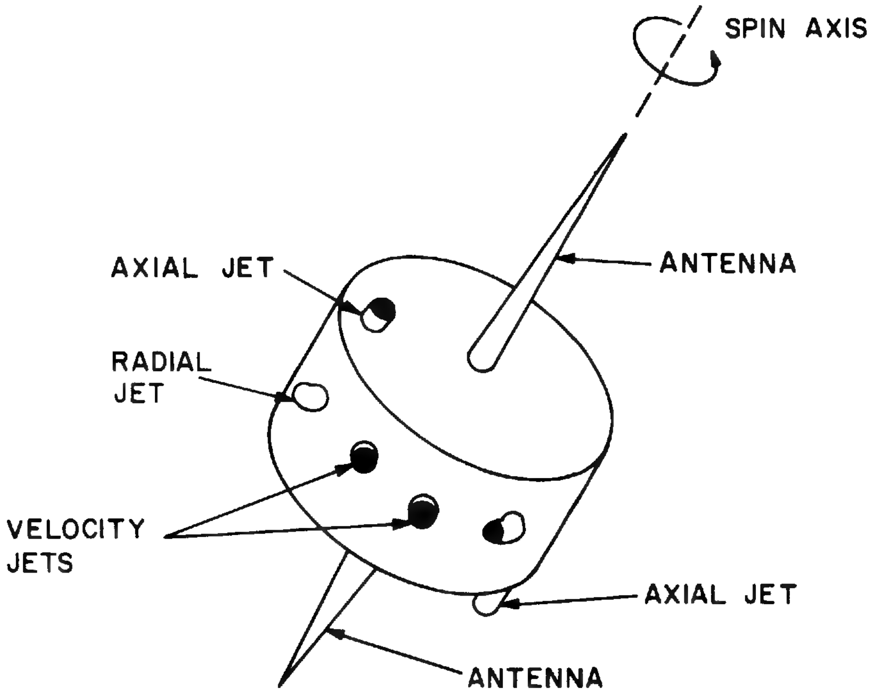


Figure 2-8. Spin-Stabilized Satellite Controls

antennas. The satellite is constructed in two parts with both parts having radial jets. The inner part is concentric with the outer part and contains the communication antennas and the communications package. The satellite is launched and injected into orbit in the usual manner. The whole satellite is spin stabilized using the outer radial jets. After the satellite is stabilized with the desired orientation, the inner radial jets spin the inner part in the opposite direction to counter the initial spin. This results in a despun inner platform, which is stationary with respect to earth. The despun platform is oriented to such a position that the communication antennas point continuously toward the earth. This arrangement allows the use of high gain directional antennas to concentrate the majority of the radiated energy in the direction of the sun.

The Phase II DSCS satellites will use a despun platform with four high gain antennas. Two steerable narrow beam antennas will be used for communications between and within regions of high traffic density. Two horn antennas will provide for earth communications between facilities outside the narrow beam coverage. The antenna arrangement proposed for the Phase II satellites is shown in figure 2-6.

e. Characteristics of the IDSCS Satellites

(1) IDCSP Satellites. These satellites are double frequency conversion, hard-limiting repeaters that are placed into near synchronous equatorial orbits at various altitudes averaging about 18, 200 nautical miles. At this altitude, the satellites drift

from west to east (relative to the earth) at about one degree of longitude per hour. The satellites are spin stabilized and solar-cell powered. The shape of the satellite is as shown in figure 2-9.

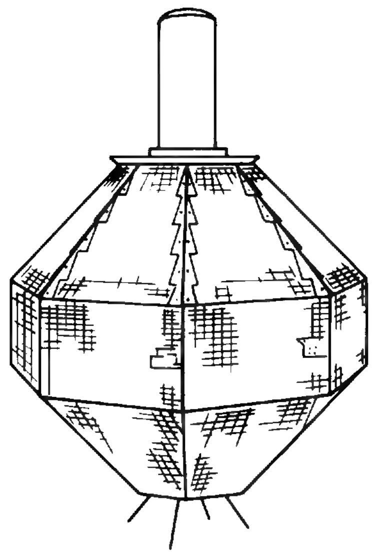


Figure 2-9. IDCSP Satellite

The satellite is 36 inches in diameter, 32 inches high, and weighs about 100 pounds. The upper cylinder contains two bicone antennas with a toroidal pattern (antenna gain 3 to 5 dB). Four telemetry antennas extend from the bottom of the satellite. Frequency modulation of the RF carriers is used on both the up links and the down links. The up-link frequencies vary from about 7986 to 8005 MHz and the down-link frequencies vary from about 7267 to 7286 MHz. The beacon frequency is about 7299 MHz and the telemetry frequency is about 400 MHz. A traveling-wave tube is used for the transmitter RF amplifier.

The use of hard-limiting RF amplifiers in the receiver results in a requirement for "power balancing" by the earth terminals prior to establishing adequate communications. A characteristic of hard-limiting amplifiers is that two signals of equal strength are amplified equally, but if the two signals are unequal the stronger signal will be amplified more than the weaker, and in some cases the stronger signal will completely capture the amplifier to the exclusion of the weaker signal. Hence, two earth terminals in establishing communications must adjust their transmitter powers to achieve a "power balance" before an optimum communication link can be established.

(2) Phase II DSCS Satellites. These satellites are under construction and only general characteristics are available. These satellites will use tunnel diode receivers and traveling-wave tubes for the transmitter RF power amplifier. They will be launched into synchronous equatorial orbits and will be spin stabilized with a despun antenna platform. The proposed shape of the satellite is shown in figure 2-6. The satellite will be 9 feet in diameter, 12 feet high, and will weigh approximately 1000 pounds. Two high gain, ground controllable antennas will provide large area

coverage. Provisions will be made for generation of about 520 watts of power with backup nickel-cadmium batteries.

2.4 EARTH TERMINAL CHARACTERISTICS

Communication satellite earth terminals generally are located in areas remote from the actual users of these communications. This is necessary to minimize RF interference to the satellite communications. Characteristic of this remoteness is a need for interconnect links to permit communication flow to and from the users of the satellite systems. These interconnect links are usually via telephone cables or microwave radio with normal terminal equipments.

Earth terminals generally have a single large antenna, a highly sensitive receiver, a powerful transmitter, multiplex equipment, modulating-demodulating equipment, and telemetry equipment.

a. Antennas. Earth terminal antennas are highly directional, high gain antennas capable of transmitting and receiving signals simultaneously. Generally, large, high gain, parabolic antennas are used with some form of Cassegrainian feed.

Three sizes of parabolic-type antennas are currently in use with the Phase I IDSCS earth terminals: the AN/FSC-9 uses a parabolic antenna 60 feet in diameter; the AN/MSC-46 uses a parabolic antenna 40 feet in diameter; and the AN/TSC-54 uses a cluster of 4 parabolic antennas, each 10 feet in diameter, which, in combination, are equivalent to a parabolic antenna 18 feet in diameter.

b. Receivers. All satellite communication earth terminals are equipped with specially designed, highly sensitive receivers. These highly sensitive receivers are required to overcome the down-link power limitations mentioned in paragraph 1.7.1 and to permit extraction of the desired communication information from the received signal. All of the terminals currently in use in the Phase I IDSCS system utilize specially designed preamplifiers mounted directly behind the antennas. The preamp noise temperatures vary with the sizes of the earth terminals. The preamp noise temperature of the AN/FSC-9 is 55° Kelvin (K); that of the AN/MSC-46 is 82° K; and the AN/TSC-54 is 120° K.

c. Transmitters. All earth terminal transmitters generate high power signals for transmission to the communication satellites. The combination of high powered transmitters and highly directional, high gain antennas is necessary to overcome the up-link limitations mentioned in paragraph 1.7.2 and to ensure that the signals received by the satellite are strong enough to be detected by the satellite. Although various arrangements of functional components are possible in transmitters, all the transmitters in use in the Phase I IDSCS earth terminals have the same general arrangements. Each IDSCS transmitter has an exciter/modulator and a power amplifier. The modulator accepts the baseband input from the terminal equipment and modulates an IF carrier. The exciter translates the IF signal to the up-link frequency and amplifies it to the level required by the klystron of the power amplifier. All IDSCS transmitters use specially cooled klystrons in their power amplifiers. The output power of the AN/FSC-9 is variable from 10 W to 20 kW; that of the AN/MSC-46 is variable from 100 W to 10 kW; and that of the AN/TSC-54 is variable from zero to 5 kW.

d. Telemetry Equipment. Telemetry equipment is included in all communication satellite systems to permit monitoring of the operating conditions within the satellite. Telemetry can be used also for remote control of satellite operations such as energizing axial jets for changing the spin axis of the satellite. In the Phase I IDSCS system telemetry information is transmitted in the 400-MHz band and is the responsibility of the Air Force. (A normal Navy earth terminal will not have a 400-MHz capability.)

e. General Description of DSCS Earth Terminals. There are three types of earth terminals currently in use in the DSCS: AN/FSC-9, AN/MSC-46, and AN/TSC-54. The two AN/FSC-9 earth terminals were built originally for the ADVENT program, were modified later for the SYNCOM program, and finally were modified for the IDCSP program. The AN/MSC-46 and AN/TSC-54 equipments were built for the IDCSP program.

(1) AN/FSC-9. The AN/FSC-9 terminals are permanent installations located at Fort Dix, New Jersey, and Camp Roberts, California. They are used as the principal terminals for communication links to Europe and to the Pacific respectively. A 60-foot parabolic antenna is mounted on a 60-foot steel antenna tower on a concrete foundation 30 feet deep and 84 feet in diameter. The antenna mount includes a bridge superstructure that acts as a counterweight and serves as a housing for electronic equipment. The estimated weight of the antenna is 190 tons. A 200-foot covered passageway connects the antenna to a 6000-square foot operations building. Additional details are shown in table 2-1. An AN/FSC-9 is shown in figure 2-10.

(2) AN/MSC-46. The AN/MSC-46 is a transportable communication satellite terminal that is housed in three vans. A rigid radome (not supplied with the terminal) is usually installed over the antenna. Power is furnished by three diesel generators (supplied as a part of AN/MSC-46) of 100 kW each, or local commercial power may be used if available. The complete terminal, including the disassembled antenna, weighs 114,000 pounds but it can be transported by three C-130E aircraft. After arrival on site, the terminal can be assembled by a crew of eight trained men. Additional details are shown in table 2-1. An AN/MSC-46 antenna with its pedestal is shown in figure 2-11.

(3) AN/TSC-54. The AN/TSC-54, the smallest of the Phase I IDSCS earth terminals, is a highly transportable communication satellite terminal. The antenna, klystron and preamplifier are mounted on a trailer and the remainder of the terminal equipment is in an equipment shelter. Power is supplied by a trailer-mounted diesel generator. The complete terminal weighs 19,500 pounds and can be transported by C-133E aircraft or H-37 helicopter; or it can be towed by suitable trucks over unimproved terrain by attaching "goat" mobilizers (furnished with the terminal) to the equipment shelter. A well-trained, experienced crew of six can set up or dismantle the AN/TSC-54 in less than two hours. A rigid radome (not supplied with the terminal) is available for semipermanent installations where required. Additional details are shown in table 2-1. An AN/TSC-54 is shown in figure 2-12.

2.5 SATELLITE ACQUISITION AND TRACKING

An essential operation in establishing communications via satellite is the acquisition of the satellite by the earth terminal antenna and subsequent tracking of the satellite. Initial acquisition depends upon an exact knowledge of the satellite's position which, in combination with the geographic location of the earth terminal, enables the computation of accurate antenna pointing information. The degree of difficulty in acquiring and tracking a satellite is determined largely by the satellite's orbital parameters.

Figure 2-10. AN/FSC-9 Satellite Earth Terminal

Figure 2-11. AN/MSC-46 Antenna and Pedestal

Figure 2-12. AN/TSC-54 Satellite Communication Terminal

Table 2-1. Principal Characteristics of DSCS Earth Terminals

EQUIPMENT PARAMETERS	AN/FSC-9	AN/MSC-46	AN/TSC-54
PHYSICAL			
Type Housing:	Permanent construction	3 vans 1 antenna 3 power units	1 shelter 1 antenna 2 power units
Terminal Weight:	-	114, 000 lb	19, 500 lb
Type Installation:	Permanent/ ground based	Movable/ground based	Mobile/ground based
TRANSPORTABILITY			
Aircraft:	-	C-130E(3)	Helicopter or C-133E
Overland:	-	Truck transported	Ground transported
TECHNICAL			
Power Output:	Variable, 10 W to 20 kW	Variable, 100 W to 10 kW	Variable, 0 W to 5 kW
Modulation:	FM and spread spectrum	FM and spread spectrum	FM and spread spectrum
Bandwidth: (Max. RF baseband)	50 MHz (-3 dB)	40 MHz (-1 dB)	40 MHz (-1 dB)**
Freq Range			
Receive:	7. 25 to 7. 75 GHz	7. 25 to 7. 75 GHz	7. 25 to 7. 75 GHz
Transmit:	7. 9 to 8. 4 GHz	7. 9 to 8. 4 GHz	7. 9 to 8. 4 GHz
Communications Capacity Installed:	11 voice* 1 TTY 1 TTY O/W	11 voice* 1 TTY 1 TTY O/W	1 voice 1 TTY 1 TTY O/W
Preamp Noise Temperature	55° K	82° K	120° K
Antenna			
Half Power Beam Width:	0. 15°	0. 17°	0. 5°
Size/Type:	60 ft dia, parabolic	40 ft dia, parabolic	18 ft effective dia, 4 10-ft dish clutter
Configuration:	Cassegrain feed	Cassegrain feed	Cassegrain feed
Radome:	None	*** Rigid, 68 ft dia	**** Rigid, 41. 4 ft dia
Primary Power Requirements			
Voltage:	440 V	120/208 V ±10%	120/208 V ±5%
Phase:	3	3	3
Frequency:	60 Hz	50/60 Hz ±5%	400 Hz ±2%
KVA:	750	less than 200	45

* An auxiliary wide-band input of 0. 3 to 500 kHz or 0. 3 to 252 kHz (up to 60 voice channels) can be accommodated.

** Receive bandwidth limited by IF filter to 10 MHz, RF bandwidth is 40 MHz.

*** Rigid radome is not furnished with terminal, but weight is included in total weight.

**** Rigid radome is not furnished with terminal, but is used as required by environmental conditions.

Acquisition and tracking of a synchronous satellite are relatively simple because the satellite appears to be stationary. Acquisition of a near synchronous satellite is relatively simple because of the slow relative motion of the satellite; however, the satellite's relative movement is enough that accurate tracking is required to keep the narrow beam antenna pointed toward the satellite. Satellites in medium altitude circular orbits or in elliptical orbits are more difficult to acquire and also to track because of their relatively rapid changes in position.

2.5.1 Orbital Prediction

a. Ephemeris Data. In order to be able to supply antenna pointing information to earth terminals, it is necessary to know with a high degree of accuracy the orbital parameters of the satellite. A table showing the calculated positions of a satellite (or any heavenly body) at regular intervals of time is called an ephemeris. The ephemeris of a satellite is calculated from its orbital parameters and a knowledge of the physical laws of motion. After the ephemeris data of a satellite are determined it is possible to predict, for any given location, the apparent track of the satellite as viewed from that location.

b. Orbital Tracking. The constants defining an orbit are initially obtained by the process of tracking. At the time of launch, the rocket is tracked by radar from "lift off" to injection, and then until it passes out of sight. The recorded tracking data obtained in this way is sufficient for making rough predictions of the orbit. These predictions are made rapidly with a computer and sent to other tracking stations in other parts of the world. The other tracking stations around the world watch for the satellite during its first trip and record additional data which enables more precise predictions to be made. Thus, during the first week of orbiting, tracking stations all around the world are obtaining progressively more accurate data concerning the satellite. These data are put into a computer where corrections of earlier estimates of the orbit are made.

Once the initial predictions are complete and the satellite link becomes operational there is very little change in these calculations. The orbits will change slightly over a period of time; however, these changes are so gradual that predictions will be accurate enough to be used for weeks or even months without further corrections. When the orbits are known precisely, an ephemeris can be calculated for each satellite of the system.

2.5.2 Antenna Pointing

Antenna pointing instructions are derived from the ephemeris of a satellite. These instructions must, however, be computed separately for each ground station location. A satellite which bears due south of station A at an elevation of 25 degrees may simultaneously bear due southeast of station B at an elevation of 30 degrees. Antenna pointing instructions are determined by taking into consideration the orbital prediction and the latitude and longitude of each ground station.

a. Ephemeris Coordinate Transformation. It is convenient to express the ephemeris in terms of a geocentric coordinate system; that is, a coordinate system whose center is the center of the earth rather than some point on the surface of the earth. Pointing instructions are obtained by converting the geocentric coordinates to local coordinates

by a further calculation. The latitude and longitude of the earth terminal must be accurately known in order to make this conversion.

While the use of modern computers for orbital calculations permits rapid calculations in any coordinate system desired, an ephemeris should be considered to be a table giving satellite position relative to the earth as a whole. The calculations that convert geocentric coordinates to local coordinates are called coordinate transformations.

From the standpoint of acquiring radio contact with a satellite, the only important local coordinates of position are bearing and elevation. Knowledge of the bearing and elevation of a satellite at the time planned for acquisition permits the antenna to be properly pointed. In addition to position, the operator of an earth terminal requires knowledge of the velocity at which the satellite is approaching, in order to properly adjust the receiver for the doppler shift. Thus predictions of both position and velocity must be taken from the ephemeris and transformed into local coordinates. Since the Phase I IDSCS satellites are in near synchronous orbits, their relative motions are quite slow; therefore, the change in frequency due to the doppler effect is very small and poses no significant problem.

b. Control Center Information. The use of satellites to set up particular communication links requires planning. Varying and contingent needs of users must be considered. With a limited number of either random orbit or quasi-synchronous satellites, it is possible that there may be no satellite in the common view of certain pairs of ground stations for minutes or hours at a time. Also, there may be a failure of electronic equipment. Planners must take all of these things into consideration in order to make best use of the satellites.

Antenna pointing instructions are calculated for planned satellite acquisitions and for additional acquisitions to provide reliability in event of satellite equipment malfunction. In the IDSCS a central computer in the Air Force Satellite Control Facility (SCF) performs these calculations for each earth terminal location. The SCF computer printouts, distributed at least a month in advance, list antenna pointing and beacon identification information for each satellite that will become visible to each terminal.

The Satellite Communications Control Facility (SCCF), operated by the DCA, schedules operating time for the use of the various satellites by the three services. The Navy Satellite Operations Center (NSOC), under the direction of the Naval Communications Command, allocates Navy-assigned operating time to Communications Area Master Stations (CAMS) which in turn designate pairs of earth terminals to use the assigned time.

2.5.3 Acquisition

The acquisition of satellite signals by a ground station equipped with large antennas and operated at microwave frequencies places severe requirements on the acquisition system, particularly if the satellite is in a medium altitude circular orbit or in an elliptical orbit.

These requirements can be divided into two problem areas: spatial-time uncertainties and frequency variations. The spatial-time acquisition (acquisition of a signal at some point in space at some instant in time) must also involve acquisition of the signal frequency.

a. Spatial-Time Factor. Very accurate antenna pointing data will be available to the earth terminal from the SCF. However, due to equipment limitations it is necessary to conduct a small search about the predicted location of the satellite in order to make initial contact. This searching involves either manually or automatically scanning a small area around the point where the satellite appearance is predicted. Upon initial reception of the beacon signal from the satellite, the tracking receiver generates error signals which direct the servo mechanism of the antenna to automatically position the antenna in the direction of maximum signal; at this time the system is transferred to the auto-track mode of operation.

b. Timing Control. Timing signals for the entire system are transmitted by the Army satellite terminal at Camp Roberts, California, to Fort Dix, New Jersey, and Helemano, Hawaii. Fort Dix retransmits these timing signals to all terminals in the Atlantic-European-African area, and Helemano transmits the signals to all Pacific sites.

c. Frequency Control. The frequency of a radio signal received from a satellite generally is not exactly the assigned down-link frequency. Since doppler effect is the principal cause of variations in the received frequency, the extent of these frequency variations is quite dependent upon the orbital geometry of the satellites. The greatest frequency variations are observed in signals from satellites in medium altitude, circular orbits and from those in elliptical orbits. The smallest frequency variations are observed in signals from satellites in near synchronous and synchronous orbits where the doppler effect is minimal or nonexistent. Considerable doppler effect can be caused in aircraft earth terminals by the high speeds of the aircraft. Additional relatively small frequency variations in satellite signals are caused by instabilities in ground- and satellite-generated frequencies. Regardless of the causes of these frequency variations they do complicate the acquisition of the satellite RF baseband signal.

Numerous elaborate electronic circuits have been designed to automatically compensate for large frequency variations in satellite received signals. The designs that provide compensations for large doppler effects are the most complicated. Nearly all of these designs include circuits for comparing the received satellite signal with a highly accurate frequency standard tuned to the satellite's assigned frequency and circuits for using the results of this comparison to modify the tuning of the earth terminal receiver. In some designs a comparison of the received beacon frequency with the assigned beacon frequency has been used to generate an RF receiver tuning correction.

Because the IDCSP satellites are in near synchronous orbits, doppler effects are minimal and elaborate tuning of the RF receivers is not necessary. Since standard FM modulation is used for modulating the RF baseband, the phase-lock loop (or automatic phase-control) circuit can be used to ensure proper RF tracking of the received satellite signal. Variations in the received satellite signal do not exceed the operating range of the phase-lock feedback technique so no further tuning correction systems are required.

2.5.4 Tracking

When a particular satellite has been acquired, the earth terminal antenna must continue to track that satellite for as long as it is to be used as the communication relay. Two of several methods of tracking are programmed tracking and automatic tracking.

a. Programmed Tracking. In programmed tracking the known orbital parameters of the satellite are fed into appropriate computation equipment to generate antenna pointing angles. The antenna pointing angles are fed as commands to the antenna positioning servomechanisms which point the antenna in the required direction. The amount of data and computation involved in using programmed tracking to point narrow beamwidth antennas is quite extensive. In addition, some deviations from calculated pointing angles arise as a result of antenna mount flexure and atmospheric and ionospheric bending of radio waves. Since these uncertainties exist, programmed tracking is not wholly satisfactory and is not used extensively.

b. Automatic Tracking. In automatic tracking antenna pointing information is generated by comparing the direction of the antenna axis with the direction from which an actual satellite signal is received. Since automatic tracking systems track the apparent position of the satellite — that is, the direction of arrival of the radio signal — knowledge of the real position of the satellite is not required. The automatic tracking system is a servomechanism and, once acquisition has been accomplished, it continually generates its own pointing data, thus eliminating the requirement for data input and computation.

Systems for automatically tracking with steerable parabolic dishes fall into two classes: sequential lobing (conical scan is an example) and simultaneous lobing (monopulse is an example). Both of these systems are employed in satellite communications applications. Both depend on the generation of an error signal when the satellite is not in the desired part of the antenna pattern and on the use of this error signal to drive the antenna pointing servomechanism.

c. Satellite Outage Time. The system specification for the DSCS allocates 120 seconds for slewing the earth terminal antennas, acquiring the satellite signal, and checking for circuit continuity at handover. This represents the minimum outage time. However, for several reasons a satellite may not be immediately available, and these reasons may combine to increase the outage time. The difference of drift velocities of the Phase I IDSCS satellites will lead to bunching of satellites with gaps causing increased outage times. In addition, when two or more satellites simultaneously occupy the common volume of the link terminal antennas, they will mutually interfere and prevent reliable communication. Other factors leading to increased outage times are satellite-sun conjunction (increased noise from the sun prevents communication), satellite eclipse (absence of power from solar cells), and satellite failures. Hence, the distribution of outage times is a complicated function of time and earth-station locations.

2.6 GENERAL TECHNICAL SUMMARY

The technology used in designing the existing Phase I IDSCS communication satellite system was the state-of-the-art technology of 1962. A conservative approach to the system design resulted in a system that will operate, but only under carefully controlled conditions. The numerous limitations outlined in the preceding paragraphs were the results of limitations of available techniques involved in the design, construction, launch, deployment and operation of the IDCSP satellites.

The states of the art affecting these techniques have all progressed at a rapid rate and improvements are possible in all major components of satellite communications systems. Technology has advanced to the point that economic restraints are the principal considerations in the design of new communication satellite systems.

Satellites presently under construction for INTELSAT IV, Phase II DSCS, and TACSATCOM all incorporate much later design techniques which will overcome many of the shortcomings of the Phase I IDSCS operations and should provide an "order of magnitude" improvement in capability and capacity.

NOTE: For a much more comprehensive discussion of general design considerations for satellite communications systems and a glossary of terms the reader is referred to reference 5.

CHAPTER 3

TECHNICAL GUIDANCE

3.1 INTRODUCTION

All Phase I IDSCS earth terminals and those proposed for the Phase II DSCS are either transportable or mobile terminals. The Department of Defense, with the concurrence of the Joint Chiefs of Staff, has established the policy that earth terminals will not be installed permanently in any overseas location and will be maintained in such a condition that they may be relocated readily from such overseas location. This policy precludes removal of terminal equipment from the vans for installation in buildings except within the territorial limits of the United States. If the equipments are to be removed from the transportable or mobile vehicles (initially provided) and installed permanently in buildings, the applicable shore station installation criteria apply.

The technical guidance of this chapter applies to Navy earth-terminal installations in which the configuration of the van-mounted equipment must be maintained intact. In view of the above, and since these terminals are designed to be self-sufficient, the technical installation criteria are not very extensive.

As a matter of Department of the Navy policy, satellite earth terminals will always be located near a permanently established naval communication station and will be installed on a semipermanent basis. Although equipments will not be removed from the vans, permanent buildings will be used to house associated peripheral equipment. Concrete foundations will be constructed to support the antenna pedestal and radome, hardstands will be installed for placement of the vans, and base or commercial power will be provided.

3.2 SITE SELECTION CRITERIA

Site selection criteria for installation of earth terminals are contained in the effective editions of DCA circular 800-2000.1 — "Criteria for Earth Station Site Selection of the Defense Satellite Communications Systems (DSCS)" and DCA circular C810-2300.2 — "Inital Defense Communications Satellite Project Earth Station/Defense Communications Systems Interface and Engineering Criteria." The DCA criteria of these publications are quite restrictive because the criteria were established to enable tracking satellites in many types of orbits. The criteria in this handbook are much less restrictive because these criteria were established for tracking only near synchronous and synchronous equatorial satellites.

3.2.1 Siting Requirements

a. General Requirements. Primary considerations in selecting a site for an earth terminal are the orbit of the satellite and the apparent path of the satellite as viewed from the earth terminal. The Phase I IDSCS satellites are in near synchronous equatorial orbits and always appear to move across the sky in the same path from the western to the eastern horizon. The Phase II DSCS satellites will be in synchronous equatorial orbits and will appear to be stationary in the sky (although the satellites may be repositioned from time to time). The apparent paths of the Phase I satellites are

determined by the latitude of the earth terminal. With the latitude of the proposed site known, figure 3-1 can be used to determine the approximate paths of Phase I satellites. Although the Phase II satellites will be synchronous (apparently stationary), they will be capable of being repositioned longitudinally. Therefore sites proposed for Phase II operations should have clear horizons for all expected satellite positions (as shown in figure 3-1 for the corresponding site latitude). Once the sky area to be tracked has been determined various possible sites can be considered.

Factors which should be considered in selecting a site for an earth terminal location include:

(1) Fairly flat terrain for minimum site preparation.

(2) Obstruction-clear horizon profile within the sector of satellite visibility, taking into account antenna elevation.

(3) Sufficient area to accommodate the number of terminals and accompanying support facilities.

(4) Protection from radio frequency interference (RFI); conversely, RFI protection from earth terminal transmission for existing facilities.

(5) Proximity to a naval communications station facility. (The facilities of a naval communications station will be used by Navy-operated satellite earth terminals as a DCS entry point.)

(6) Provision for survivability, as applicable.

(7) Acceptable environmental conditions such as an area free of possible floods or slides and having good soil-bearing characteristics.

(8) Accessibility and logistic support.

Ideally, an earth terminal should be located in a relatively flat, saucer shaped area with a clear view of that part of the sky through which the satellites are expected to travel and with hills or other natural obstructions in the northward sectors (southward in the southern hemisphere). Horizon masking in the directions of satellite rise and set should not exceed 2.5° in order that the maximum sector of satellite visibility may be obtained with the Phase I satellites. Horizon masking in other sectors will provide protection from RFI, assuming that no RFI sources lie within the horizon of the terminal in the line of sight of the antenna. (Note that even a protected location can be exposed to RFI by some propagation modes; for example, scatter and diffraction.) It is necessary to survey proposed sites to determine if there are obstructions that will mask the satellite at any particular azimuth. (See subparagraph c below.)

b. Surveying Accuracy. Accurate determination of the geographic location of the selected earth terminal antenna site is required in order that accurate antenna pointing information may be computed. Whenever possible, third order surveying accuracy (one part in 5000) should be maintained to establish the azimuth and length of the base line, the elevation of the site, and reference markers. This degree of accuracy is not required for preliminary site selection but is required for any chosen operational site.

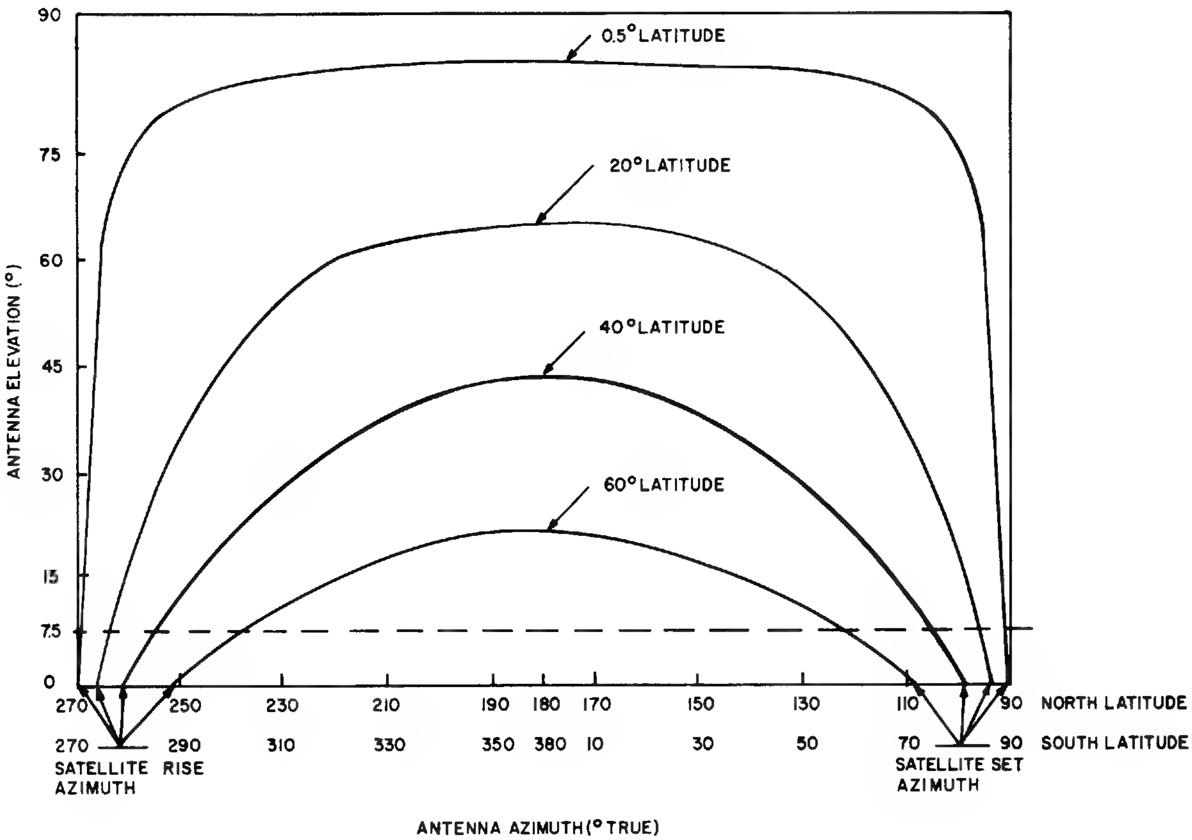


Figure 3-1. Antenna Elevation as a Function of Azimuth

c. Horizon Profile. In considering possible sites the horizon profile must be determined throughout the azimuth sector in which the satellites may appear. The earth terminal antenna beam path must have a clearance of at least 5° elevation above horizon obstructions throughout the earth terminal's sector of satellite visibility. Figure 3-1 shows antenna elevation at latitudes 0.5°, 20°, 40°, and 60° as a function of azimuth. For equatorial satellites this information may be used to determine the sector of visibility in which obstructions to the terminal-to-satellite radio path must be considered. The azimuths for equatorial satellite rise and set are shown with greater accuracy in figures 3-2 and 3-3 for site locations in northern latitudes and southern latitudes respectively. Depending on the latitude of Phase I IDSCS earth terminal sites, horizon profile clearances less than the prescribed 5° may be allowed at azimuths other than those of satellite rise and set.

d. Site Layout. For sites in the northern hemisphere, the earth terminal should be located on the south side of any building. Generators and any other auxiliary equipment should be sited to the north of the antenna. This layout should be reversed for sites in the southern hemisphere. The orbit of the satellite should be considered in laying out the site. Since there are no plans for satellites other than those in equatorial orbits, a multiple terminal site generally should have terminals placed in a north-south line; however, for terminals at the greater latitudes (approximately 40° or higher), terminals should be placed in an east-west line — this will prevent the screening of one terminal by another. A minimum separation of 350 feet between earth terminals should be maintained to reduce the possibility of radiation hazards and RFI. Locations for equipments within each earth terminal are limited by the lengths of interconnecting cable furnished with the terminal. Interconnect cables for the AN/TSC-54 are 50 feet long, for the AN/MSC-46 100 feet long with both equipments having longer power cables. (For semipermanent installations the power leads can exceed the length of the equipment power cable provided the proper size of wire for the distance and power frequency is used.) Input/output cables for connecting the operations vans to the Link Terminal Terminating Equipment (LTTE) are not supplied with the earth terminal equipments. See subparagraph 3.3.2 for further discussion of LTTE requirements. Figure 3-4 shows a typical multiple earth terminal site layout. Table 3-1 shows typical dimensions, applicable to figure 3-4, for the AN/MSC-46 and AN/TSC-54 earth terminals.

Table 3-1. Dimensions of a Typical Site Layout for 1, 2, and 3 Earth Terminals

EARTH TERMINALS	A* (ft)	B* (ft)	C* (ft)	D* (ft)	E (ft) *			F* (ft)
					1 TERM	2 TERM	3 TERM	
AN/MSC-46	225	350	100	100	325	675	1025	450
AN/TSC-54	225	350	100	50	325	675	1025	450

*See figure 3-4 for legend.

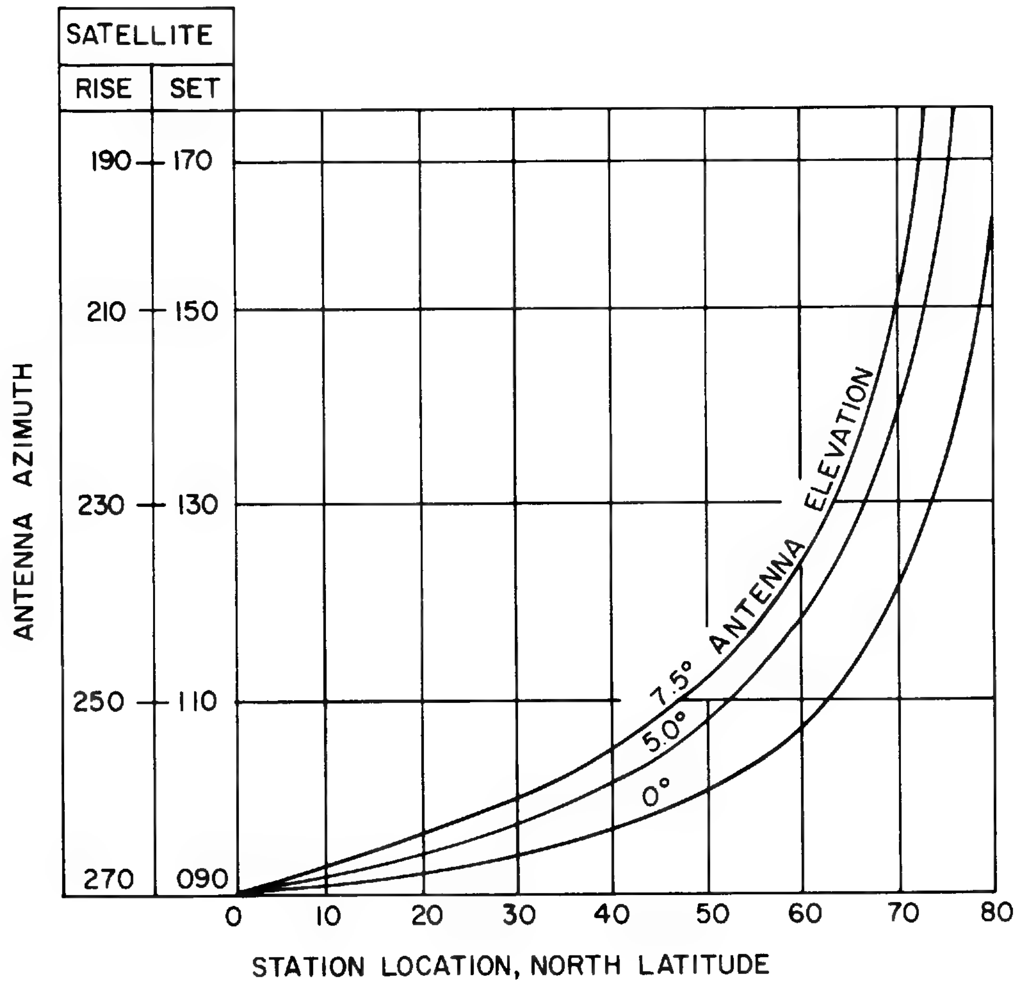


Figure 3-2. Rise and Set Azimuths - Northern Latitude

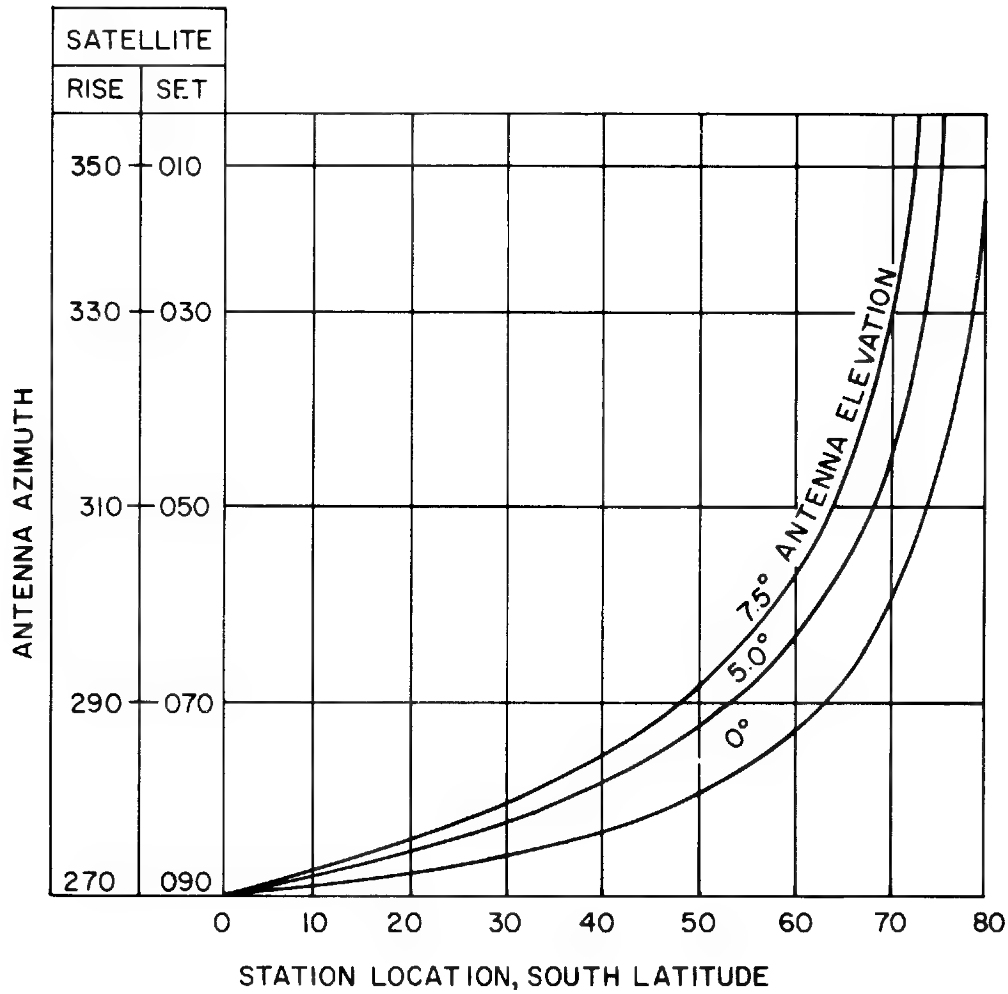


Figure 3-3. Rise and Set Azimuths - Southern Latitude

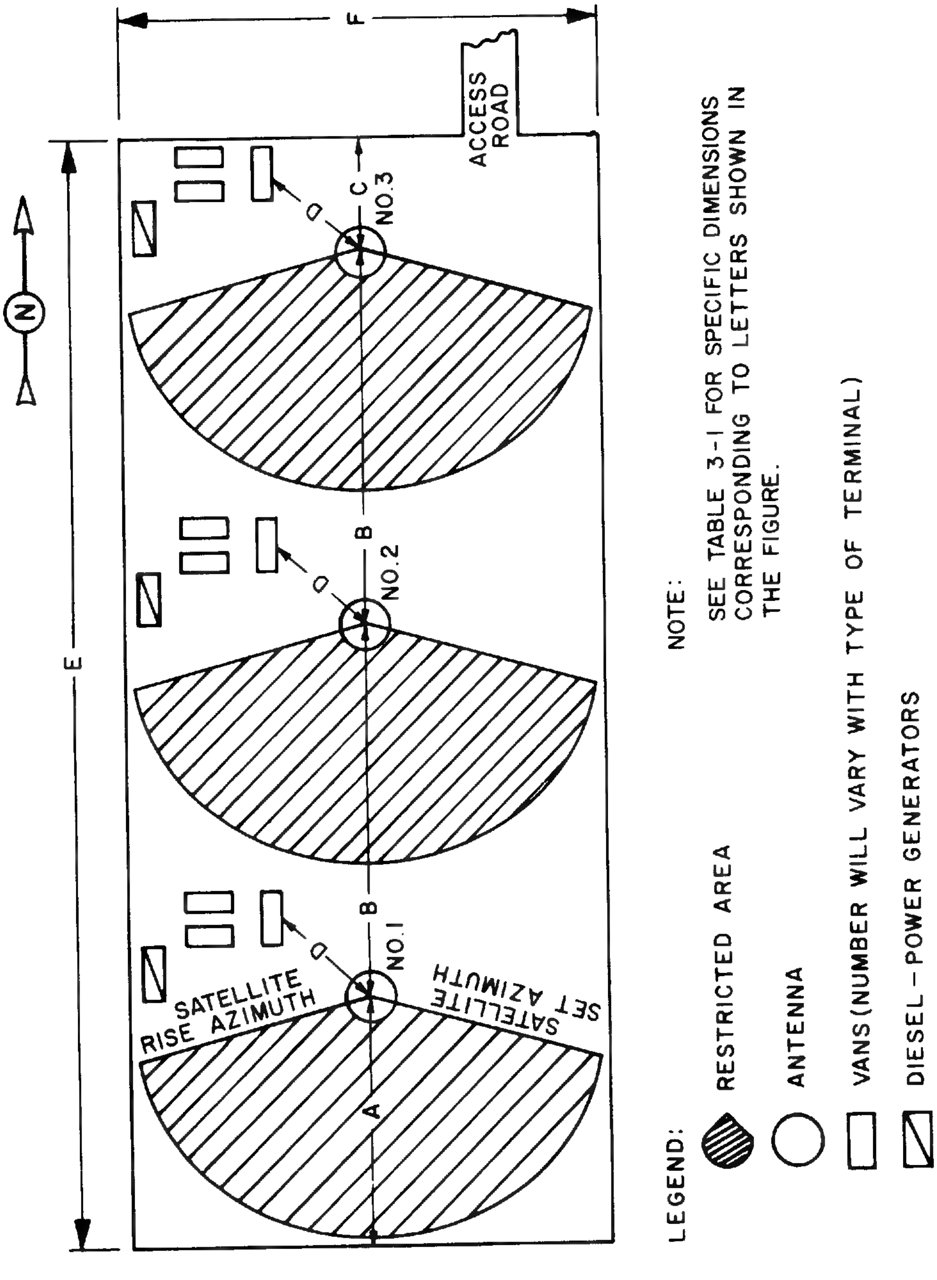


Figure 3-4. Typical Site Layout for Three Earth Terminals (Northern Hemisphere)

e. Map Requirements. In considering possible sites, a map of the general area showing specific information about the proposed site and general information about the geographic area will prove quite useful. Such a map should include access roads; arterial roads; populated areas within 5 miles of the proposed site, ammunition storage areas within 3 miles; petroleum, oil and lubricants (POL) storage areas within 1 mile; routes of existing communication lines; routes of existing power lines; military installations in the vicinity and all likely sources of RFI.

3.2.2 Environmental Requirements

The natural drainage features and soil characteristics of proposed sites and expected extremes of climate must be considered since these factors affect the work that will be required to prepare a selected site for an earth terminal installation.

a. Natural Drainage Features and Soil Characteristics. A proposed site must not be susceptible to flooding and must be protected against heavy and sustained precipitation by adequate natural drainage.

The soil characteristics will determine how much preparation will be required for any proposed site. The extremely narrow beamwidth of the antenna requires that the antenna pedestal have a firm foundation. If the soil characteristics are not suitable for supporting a heavy antenna foundation, extensive concrete work may be required to support the antenna pedestal, the antenna and the radome. Moreover, the construction of the hardstands and the auxiliary buildings may be more complicated.

b. Climate. Extremes of the local climate should be considered in selecting a site. Although the design characteristics of the Phase I earth terminals permit operation under a wide range of environmental conditions, care must be exercised in the selection of sites to ensure that the expected extreme conditions will not exceed the design specifications. For example, there are significant variations in rainfall patterns within short distances in such places as Hawaii and the Philippines.

Design characteristics for the Phase I IDSCS earth terminals are listed in table 3-2. Note that these characteristics are for limited operational periods in some instances and do not apply to continuous operation.

3.2.3 Power Requirements

Although the Phase I IDSCS earth terminal equipments include transportable or mobile motor generator sets with sufficient capacity to operate the terminals, these generators will be used in Navy terminals for emergency backup only. Base primary and secondary power should be available to each proposed site. The ease of providing such base power is an important factor in site selection.

3.2.4 Physical Survivability

Although the Phase I IDSCS earth terminals have negligible inherent survivability, the choice of proposed sites should consider the survivability requirements of the users of the terminals. If the terminal is supporting only a single user it may be collocated with and require no greater survivability than that of the user. On the other hand,

circumstances may dictate that a terminal serving several users be located at least 50 miles from a prime target area. To improve survivability, two or more terminals comprising an earth station should be separated as widely as local conditions will permit. If possible, a natural protection of high terrain between terminals should be sought so as to minimize concurrent damage from a single blast. Survivability requirements may dictate use of redundant interconnect links from a remote terminal location to provide a greater degree of survivability.

Table 3-2. Design Characteristics of AN/MSC-46 and AN/TSC-54 Earth Terminals

Ambient Air Temperature (design characteristics):		
	Maximum	Minimum
AN/MSC-46	+125° F	-25° F
AN/TSC-54	+120° F*	-25° F*
Relative Humidity (design characteristics): (operating)		
	Maximum	Minimum
AN/MSC-46	97% at 80-85° F	5% at 125° F
AN/TSC-54	100% up to 85° F	5% at 120° F
Maximum Wind Velocity (miles/hour) (design characteristics):		
(Without radome:)	AN/MSC-46 Antenna	AN/TSC-54 Antenna
Operational	30 (gust factor of 2)	30 (gust factor of 1.5)
Nonoperational	60 (gust factor of 1.33)	60
Survival (stow position)	120	125 (1/2 hour warning to place in stow position)
(With rigid radome:)	AN/MSC-46	AN/TSC-54
Operational	170 (gust factor of 1.33)	150

*Maximum design operating time for these conditions has been based on 4 hours performance capability.

3.2.5 Electromagnetic Interference

Communication satellite earth terminals should be sited in locations that minimize electromagnetic interference to the earth terminal from other radiation sources and also minimize electromagnetic interference to other electronic devices in the general area. The extremely low levels of the RF signals received by the Phase I earth terminals from IDCSP satellites require that extraneous electromagnetic interference be considered carefully in site selection. Similarly, the relatively high power of the earth terminal transmitted signals requires careful consideration of possible electromagnetic interference to nearby electronic equipments.

In the selection of sites both of the above kinds of electromagnetic interference should be considered, particularly in the azimuth sector involved in the expected sky coverage area.

3.2.6 Radiation Hazard Safeguards

Radiation hazards to personnel, fuels and ammunition may exist due to the radiated power from the earth terminals.

a. Personnel Hazard. A potential hazard to personnel exists in proximity to the antenna assembly of an earth terminal employing large aperture antennas and high powered transmitters. The acceptable maximum value of RF power density for continuous personnel exposure is 10 mW/cm^2 (average). The vertical cross section of the radiation hazard volume, based on the above maximum RMS RF power density, for the AN/MSC-46 earth terminal is shown in figure 3-5; that of the AN/TSC-54 is shown in figure 3-6. The radiation hazard volume at any proposed site relative to the required sky area coverage is a factor to be considered in site selection.

b. Fuel and Ammunition Hazards. Radiation hazards to fuel and ammunition vary depending on the types of fuel and ammunition concerned and the degree of exposure (in or out of shipping container, etc.). Allowable power density levels for fuel and ammunition are prescribed in the effective edition of NAVORD OP 3565/ NAVAIR 16-1-529 — "Technical Manual Radio Frequency Hazards to Ordnance, Personnel, and Fuel." Although some items of ordnance are hazardous with power densities as low as 0.5 mW/cm^2 at the Phase I IDSCS frequencies, allowable power densities for fuel and ammunition generally are higher than those prescribed for personnel.

c. Transmitter Power Cutout Cam. To reduce the likelihood of inadvertent radiation hazards, a transmitter power cutout cam is provided. These cams should never be set for an elevation angle of less than 7.5°.

3.2.7 Collimation Facility

For Navy earth terminals in the Phase I IDSCS collimation facilities are not required.

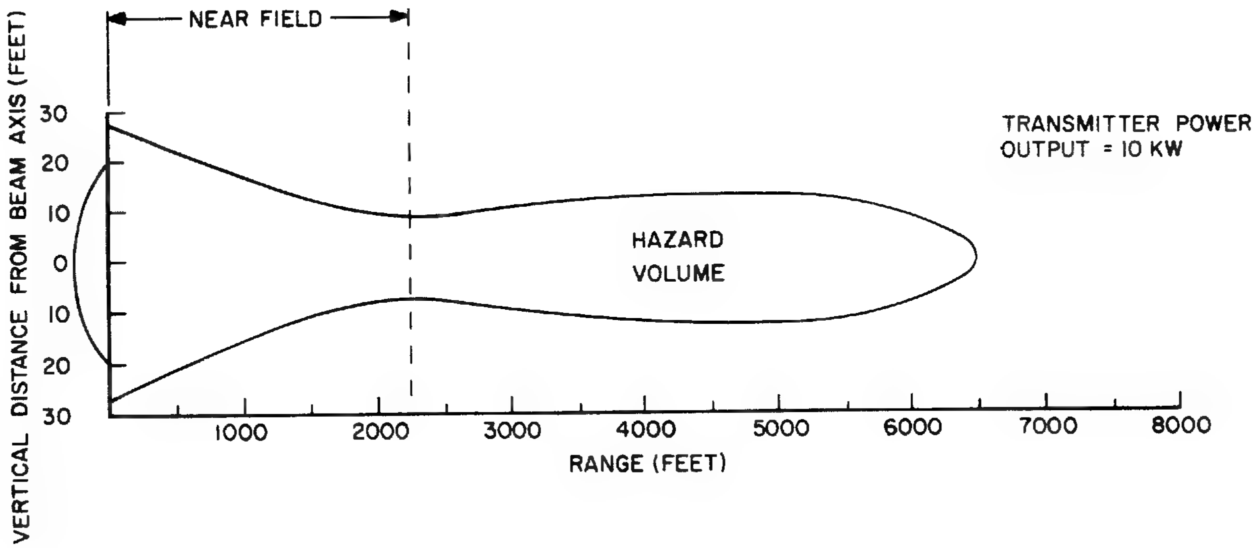


Figure 3-5. Vertical Cross Section of Radiation Hazard Volume for Power Density Level Contour (10 mW/cm^2) for Satellite Earth Terminal AN/MSC-46

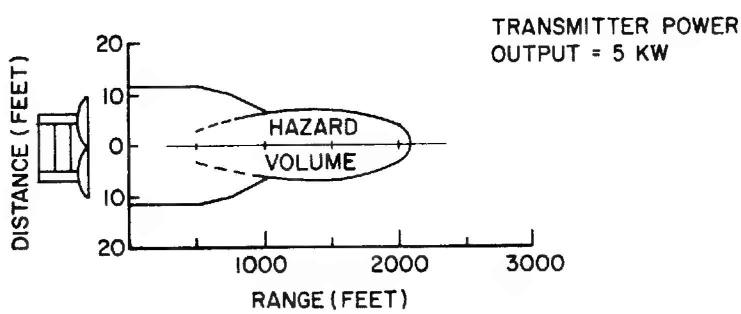


Figure 3-6. Vertical Cross Section of Radiation Hazard Volume for Power Density Level Contour (10mW/cm^2) for Mobile Satellite Earth Terminal AN/TSC-54

3.2.8 Access to Naval Communications Station

Navy satellite earth terminals will be connected either directly to a naval communications center or via a naval receiver station to its communications center. The type of interconnect link between an earth terminal and a naval communications station will depend upon the distance between the two locations and the conditions of the intervening terrain. Depending on local conditions, telephone system, hardwire, microwave, or troposcatter radio may be used. The maximum distance allowable for DC signaling via hardwire is two miles.

3.2.9 Site Survey Data

Much of the criteria to be considered in the evaluation of proposed sites can be determined from large scale topographic maps and other types of information about the local area. Preliminary evaluation of possible sites, based on available documentation, will eliminate some sites as obviously unsuitable and will direct attention to promising sites to be investigated further by an on-site survey team. Documentation of presurvey information concerning promising sites will facilitate the tasks of on-site survey teams and will expedite their survey. Forms for recording presurvey and on-site survey data are included in appendixes A and B respectively.

3.3 SITE PREPARATION AND INSTALLATION

After a particular site has been chosen, the installation of the earth terminal must be planned, designed and engineered to enable the operation of the terminal under the environmental conditions to be expected at the site. Although general design criteria apply to each site, reference to the technical manuals for each equipment to be installed is essential. Semipermanent installation of an earth terminal involves:

a. Preparation of the site.

b. Construction of foundations for the antenna pedestal and radome.

c. Connection of base and/or commercial power.

d. Construction of permanent buildings for the emergency generators, power switches, dummy load and LTTE.

e. Construction of hardstand area for trailer parking.

f. Preparation of semipermanent arrangements for interconnecting the various units of the earth terminals grounding the equipments and providing the necessary logistic and personnel facilities.

3.3.1 Foundations for Antenna Mount and Radome

Since the antennas for Phase I IDSCS earth terminals have very narrow beamwidths, they are very susceptible to any unintentional motion. Consequently, the antenna pedestal must have a very stable base. Because of the heavy weights of the antennas and their pedestals and the requirement for accurate antenna pointing, solid reinforced

concrete foundations are required. The extent of these foundations will vary from location to location depending on the soil characteristics and extremes of climate expected. Foldout 3-1 shows a typical foundation for an AN/MSC-46 antenna pedestal and Figure 3-7 shows a typical foundation for an AN/TSC-54 antenna pedestal. All semipermanent earth terminal installations will include radomes to protect the antenna, antenna pedestal and associated equipment. These radomes, being relatively heavy, require reinforced concrete foundations. A radome foundation should be centered on the vertical center of movement of the antenna pedestal. Foldout 3-2 shows a typical radome foundation for an AN/MSC-46; and figure 3-8 shows a typical radome foundation for an AN/TSC-54. Again, reference to technical manuals for the specific equipments to be installed, giving due consideration to the environmental characteristics of the selected site, is essential to development of installation plans.

The area between the antenna foundation and the radome foundation should be paved and sloped (1/4 inch per foot) outward to the radome foundation. Means for draining tie-down hollows and the overall enclosed area should be provided, if warranted by expected climate conditions.

3.3.2 Other Site Construction

In addition to the antenna pedestal foundation and radome foundation, construction of permanent buildings for housing peripheral equipments will be required. These peripheral equipment buildings should be constructed in accordance with the normal procedures for the local area.

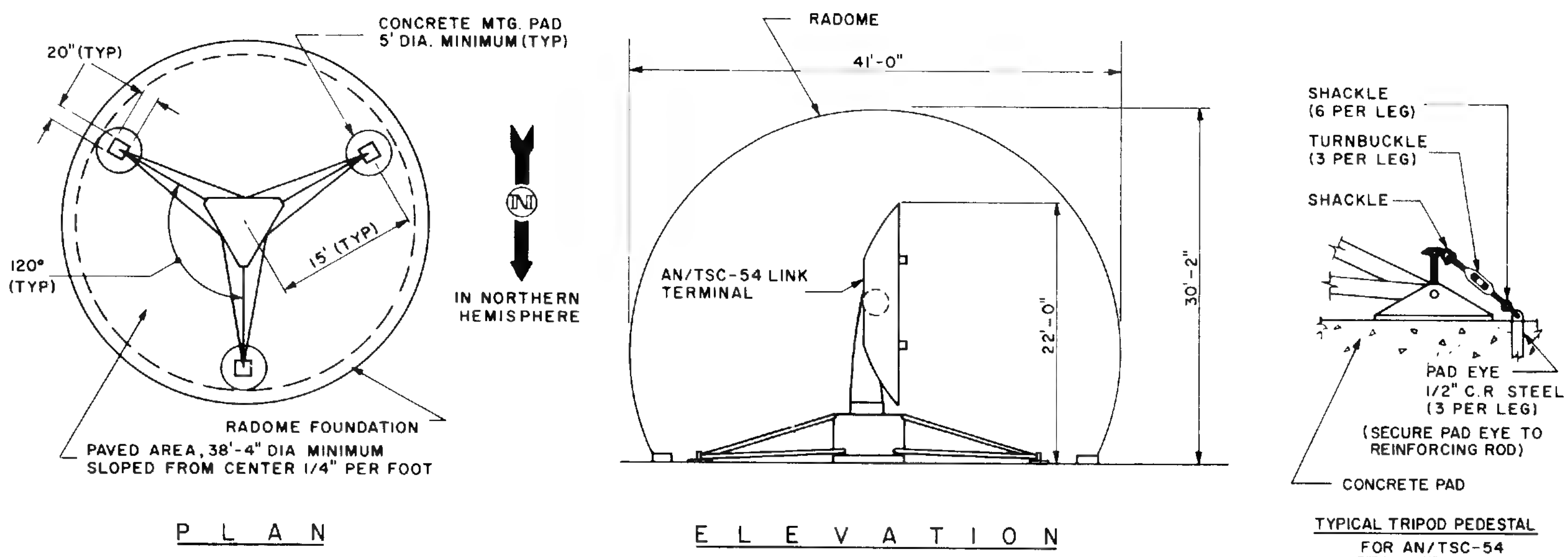
A hardstand for parking the vans should be constructed in the close vicinity and north (south in southern hemisphere) of the antenna and radome foundations. The AN/MSC-46 vans are 7 feet 10 inches wide, 29 feet long, and 11 feet high. The AN/TSC-46 operations shelter is 7 feet wide, 10 feet long, and 7 feet high.

If link terminal terminating equipment is required for the earth terminal, a building should be constructed specifically to house this equipment. In addition to space for the link equipment, space should be included for patchboards and test equipment, orderwire equipment, spare parts storage, coffee mess, head facilities and an administrative office. A microwave tower should be included if microwave is to be used.

A separate building should be constructed to house the generators furnished with the earth terminal equipments and any auxiliary converters or motor generators required to utilize base or commercial primary power. Switches to permit shifting to the various power sources should be provided.

3.3.3 Power and Emergency Power

A primary and a secondary source of electrical power should be provided for the earth terminal. These power sources can be either base-generated or commercial but they should be separate reliable sources. The generators furnished with the earth terminal equipment should be installed and wired to the equipments for use as emergency backup power. Fuel tanks for these emergency backup equipments should be installed and should be of sufficient capacity to operate the terminal equipment for one week. A dummy load should be provided for test purposes.



NOTES:

ANTENNA PEDESTAL

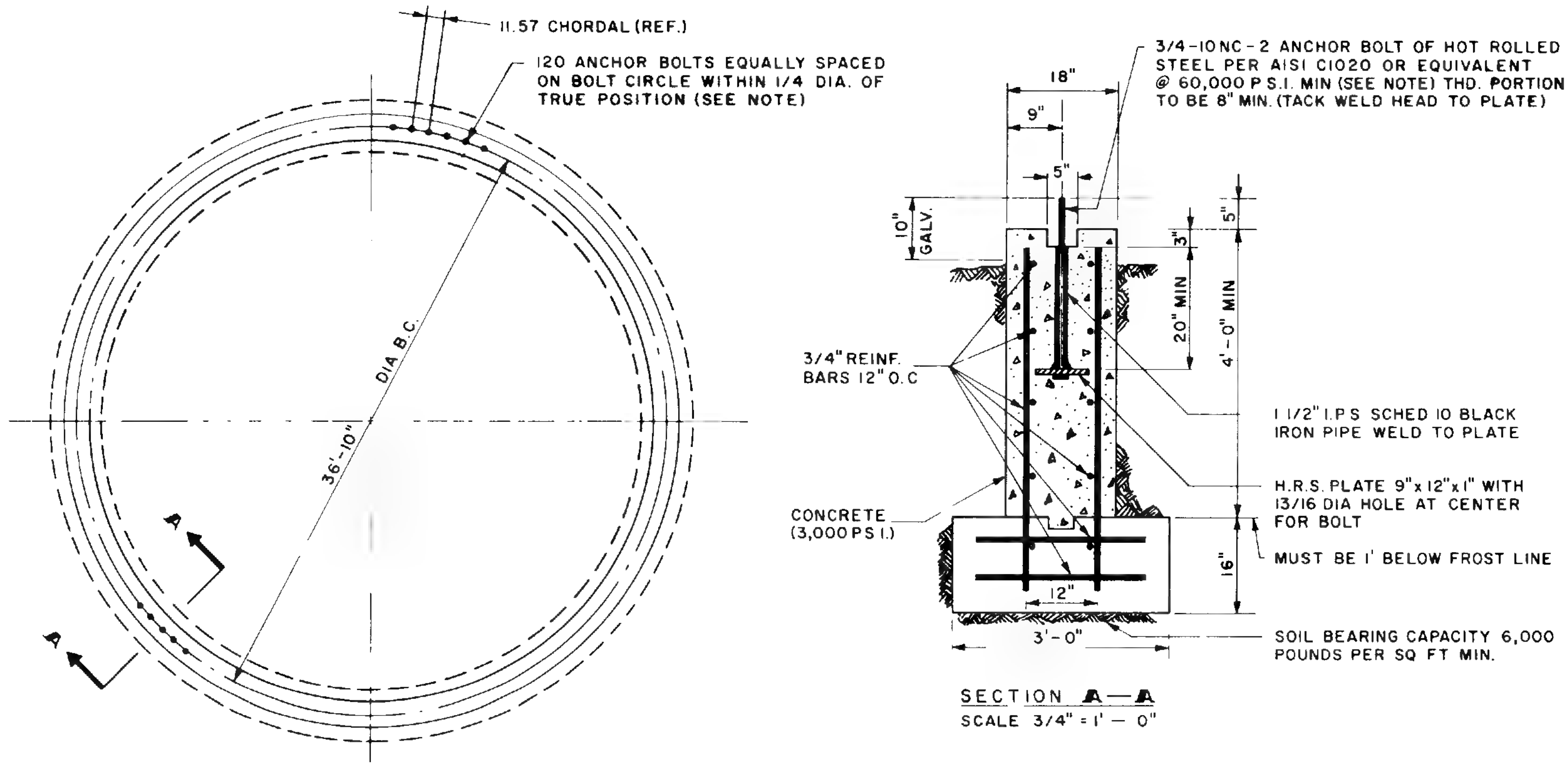
FULLY LOADED - 5400 LBS.

UNDER STATIC CONDITION OF NO WIND, OUTRIGGERS SUPPORT FULL LOAD OF 5400 LBS. EVENLY DISTRIBUTED ON EACH PAD AT 4.5 LBS/SQ. IN., THREE OUTRIGGERS, 15 FT LONG, 120° APART.

RADOME

DIAMETER ———— 41 FT.
BASE DIAMETER ———— 38 FT. - 4 IN.
WEIGHT ———— 6200 LBS.
WIDTH OF CONCRETE FOUNDATION CIRCLE ———— 1 FT - 6 IN.

Figure 3-7. Typical Foundation for an AN/TSC-54 Antenna Pedestal



NOTE

SUPPLY 3/4-10NC-2 HEX NUTS (240), 3/4 FLAT WASHERS (240), 3/4 LOCKWASHERS (240) & 3/4 FLAT WASHERS LARGE PATTERN (120), ALL OF WHICH TO BE OF GALVANIZED OR ZINC PLATED STEEL.

RADOME				
DRAG LBS	LIFT LBS.	O.T.M FT. LBS	WEIGHT LBS	WIND VELOCITY
36,000	81,000	410,000	6,200	150 M.P.H

Figure 3-8. Typical Foundation for Radome for an AN/TSC-54 Antenna

a. Detailed Requirements for AN/MSC-46. Power required for the AN/MSC-46 terminal is 120/208 volts ±5%, 3 phase, 4-wire, 60 Hz. Average power consumed is 140 kW. The three diesel engine generators of 100 kW each, which are supplied with the equipments, should be installed as emergency power backup.

b. Detailed Requirements for AN/TSC-54. Power required for the AN/TSC-54 terminal is 120/208 volts, ±10%, 3 phase, 4-wire, 400 Hz. Peak power requirement is 45 kW. For present installations, two 45 kW diesel engine generators, type PU-608 A/G, are provided. In order to utilize station power, a rotary converter JHMX60H, type MG-1, is supplied to convert the 60-Hz station power to the 400-Hz power required by the terminal. This rotary converter takes 440-volt, 3 phase, 60-Hz power and delivers 120/208 volts, 3 phase, 400-Hz power, 45 kVA. Its weight is 4380 pounds.

c. Additional Radome Power Requirements. Although self-supporting radomes are not furnished as part of the AN/MSC-46 and AN/TSC-54 equipments, such radomes are available and usually are provided for semipermanent installations. If local site temperature and/or humidity conditions are such that special ventilating or air conditioning of the radome is required, additional 60-Hz power will be required.

d. Switching Arrangements. For semipermanent installations, adequate switching arrangements should be provided so that each source of power can be connected to the earth terminal and so that the emergency generators can be connected to a dummy load for testing. These switches are not supplied with the earth terminal equipments.

3.3.4 Earth Station Circuit Flow and Interconnect Criteria

Basically, satellite earth terminals are links used to connect the technical control facility (TCF) of one communications center to the TCF of another communications center, or to a DCS TCF. Figure 3-9 shows this relationship. The TCF of the communications center is the circuit control point. All circuit control personnel stationed at the earth terminal and the LTTE building are coordinated by and under the direct control of the TCF of the communications center. Routing of individual channels within the overall baseband signal received via the satellite earth terminal for distribution to users or for relay (including the use of regenerative equipment) is a function of the TCF and not that of the satellite earth terminal or the LTTE station.

A typical circuit distribution plan showing the interconnections between a communications center and a satellite earth terminal is shown in foldout 3-3. This plan provides for analog and digital, send and receive channels to the operating van for both reception and transmission of traffic. The number of these circuits is dependent upon the type of earth terminal being used. (The AN/MSC-46 can handle up to eleven nominal 4-kHz voice channels plus two orderwire teletype circuits. The AN/TSC-54 can handle one voice channel and two teletype circuits.) Sufficient peripheral equipment (patchboard, line conditioning, voice frequency carrier telegraph (VFCT), etc.) must be provided in the LTTE building to process and distribute the circuits in accordance with foldout 3-3. This equipment must be of such quality that at least one circuit can be conditioned to the S3 circuit parameter code for AUTOVON service. NAVELEX 0101, 102 — "Naval Shore Electronics Criteria Naval Communication Station Design" contains a description of the circuit parameter codes. Foldout 3-3 shows teletype equipment for orderwire use in both the LTTE building and the operating van. The orderwire circuit extends from the operating van and the LTTE building to the TCF in the communications center. Hubber units are used at the TCF to allow operators at the TCF, LTTE, and operating van to communicate with one another and to communicate

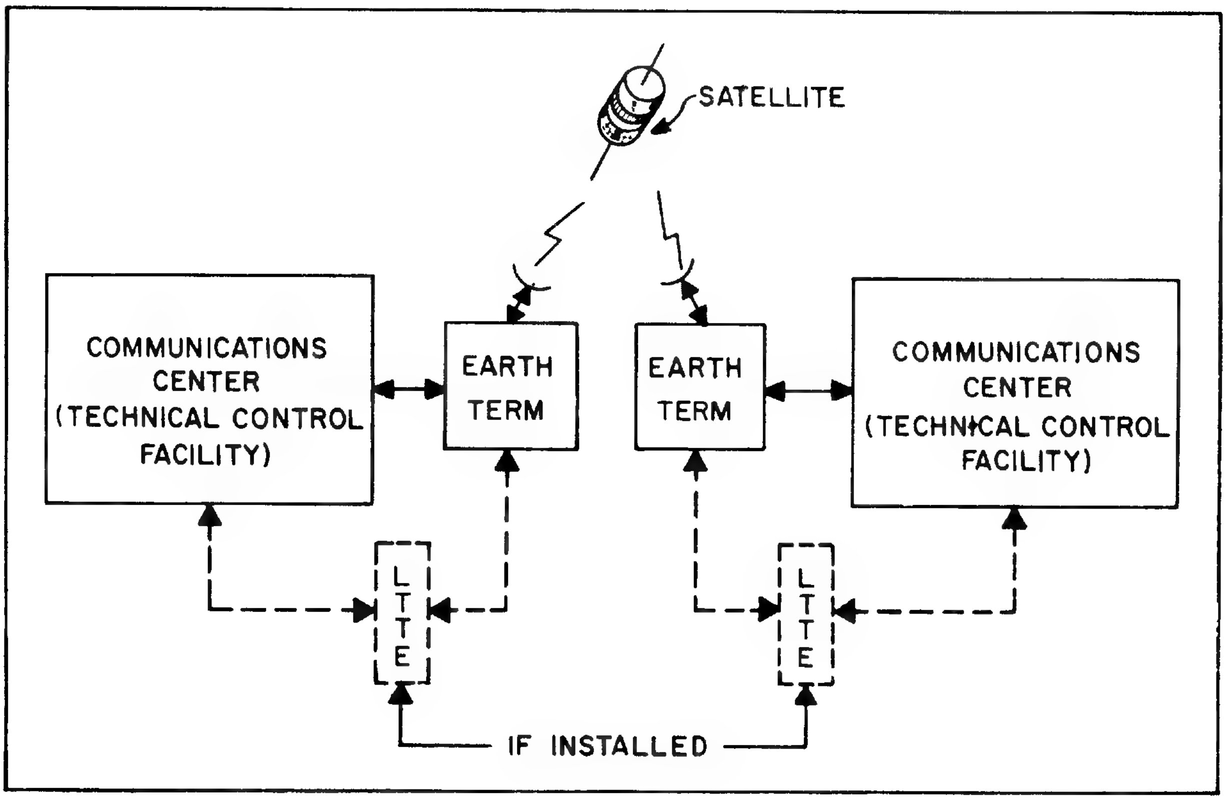


Figure 3-9. Satellite Communications Circuit

over the satellite link to the next communications center. When the LTTE and the operating van are combined into a single complex, the orderwire teletype equipment shown for the operating van would be eliminated.

The general criteria applicable to the equipment installation and wiring are identical to that given in NAVELEX 0101, 102. The cabling between the buildings and the van is standardized to the 26- and 52-twisted pair cables indicated in foldout 3-3. All DC signals are transmitted over a 26-twisted pair individually shielded cable, pressurized with nitrogen, while all audio or analog signals are transmitted over the 52-twisted pair overall shielded cable. Individual wires are solid copper, either 19- or 22-gauge; the 22-gauge being used for runs up to one mile and the 19-gauge for runs up to two miles. A minimum separation of 8 inches is to be maintained between these two cables throughout their entire run. These two cables provide approximately 100 percent spare pairs to allow for possible facility expansion. The quantity and arrangement of equipment must also be planned with provision for maintenance and for system expansion. The VFCT equipment must have one additional channel as a spare for each group of five channels or portion thereof in use.

3.3.5 Grounding Criteria

a. Equipment Grounds. No RF counterpoise ground is required. Provisions should be made for grounding the various component parts of the earth terminal for personnel safety. The equipment ground should be used as the signal ground. The combination power and signal ground should have not more than 25 ohms resistance to earth. (NAVELEX 0101, 102 contains a description of two methods of measuring the effectiveness of an installed ground.) When the LTTE building is not collocated with the earth terminal trailers, both the LTTE building and earth terminal trailers should have their own ground rods.

b. Lightning Rods. A lightning rod with proper grounding should be installed at the top of the radome (if it is not already provided).

c. Red-black Conditions. If red-black security conditions exist in an operations van or shelter, grounding shall comply with the criteria set forth in DCA 300-175-1 and NAVELEX 011120.1.

3.3.6 Other General Site Preparation Considerations

Provisions should be made to protect the various interconnect cables and the equipment coolant piping. Environmental conditions at the earth terminal site govern whether cables and piping should be installed in shallow protected trenches or on elevated protected hangers as shown in figure 3-10. Drainage features should be included for both types of cable runs.

Special precautions should be taken to assure continuous operation of the earth terminal under expected environmental conditions. In hurricane or typhoon areas, special provisions for tie-down anchors and other precautions against high velocity winds should be taken. Air conditioning and fungus preventative actions may be required in hot and humid locations. Similarly, special heating and ventilation measures should be taken in cold areas. Normal construction procedures in use for any particular area should be followed with due consideration given to the sizes and weights of the major units of the earth terminal.

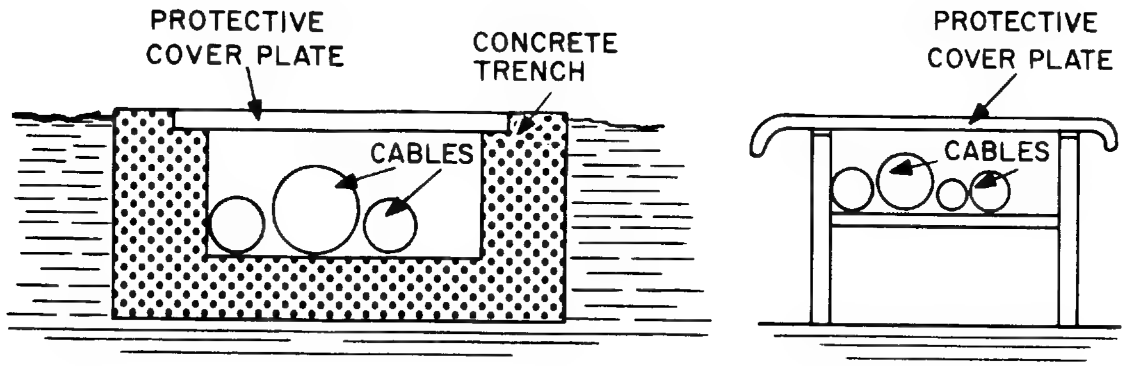


Figure 3-10. Types of Cable Runs

3.3.7 Personnel and Logistic Support

Normal shore station installations for berthing, messing and recreational facilities for operating and maintenance personnel should be available. Similarly, complete logistic support must be furnished.

APPENDIX A

PRESURVEY DATA

1. Administrative Data.
   a. Name of project ______________________________
   b. Task charge number ______________________________
   c. Site name or identification ______________________________
   d. Type of station ______________________________
   e. Operating service ( ) USA, ( ) USN, ( ) USAF, Other (specify)
   ____
   f. Location of site ______________________________
   g. Site coordinates: Latitude ______________ Longitude ______________
   Elevation ______________ As obtained from ______________
   h. Directions to site (Mark route upon the best available road or topographical map.)
   ____
   ____
   i. Owner or command controlling site (name and address)
   ____
   ____
   j. Military and civilian contacts (names and addresses)
   ____
   ____

2. Earth Terminal Data.
   a. Earth terminal(s).
   Type ______________ Number ______________
   Transmitter power ______________________________ kW.
   b. Azimuths of satellite rise and set (from true north).
   Rize azimuth ______________ Set azimuth ______________

3. Table of Maps and Plots. (Fill in paragraph a below for each map; scale should be 1:24, 000 or 1:62, 500 with a contour interval of 10 feet or less).
   a. Title ______________________________
   (1) Map series ______________________________
   (2) Type (geodetic, profile, plot, etc.) ______________________________
   (3) Territory ______________________________

(4) Source______

(5) Scale______ Date______

(6) Special data (plot size, antenna, bearing, etc.)

______

______

______

b. If not already shown on existing maps, the following items should be added during the presurvey preparation or during the site survey.

(1) Area of site, assigned or to be acquired, and route of access road (access road required is 12-foot crown width). Note possible obstructions which may block transportation of equipment to the site.

(2) Heavily populated areas within 5 miles, ammunition storage areas within 3 miles, and POL storage areas within 1 mile. Show other military installations within 10 miles.

(3) The location of possible RF interference sources.

(4) Route of communications cable, existing LOS, or tropo. (Add additional sheets for each map required.)

4. Surveying Data and Accuracy.

a. Description and coordinates of established site marker in the area to be surveyed and bearing and distance from this marker to the proposed site______

______

______

b. Surveying accuracy will be as follows:

(1) Base line azimuth;______order.
(1st, 2nd, 3rd)

(2) Length of base line;______order.
(1st, 2nd, 3rd)

Note: 3rd order accuracy, one part in 5000 or better, is desired for both (1) and (2).

(3) Site marker elevation accuracy required is ±______feet.

c. Amount of topographic data required from survey team

______

______

d. Contour interval required______feet.

e. Other______

______

5. Land Requirements.

   a. Earth Terminal

      (1) Length ______________________ feet (approximately).

      (2) Width ______________________ feet (approximately).

      (3) Area ______________________ acres.

   b. Auxiliary Facilities. List the minimum area required for auxiliary facilities, (e.g., interconnect link terminal facility, storage sheds, barracks, fuel and water tanks, etc.)

Facility	Length (ft.)	Width (ft.)	Area (acres)
________	________	________	________
________	________	________	________
________	________	________	________

6. Power Requirements. (Power requirements must include auxiliary equipment and facilities, if applicable.)

   a. The anticipated power requirements are as follows:

      Total technical load ______________________ kVA.

      Total nontechnical load ______________________ kVA.

      Total power requirements ______________________ kVA at __________ Hz, __________ phase, __________ volts at a power factor of __________

   b. Allowable voltage and frequency deviations from rated values:

      Voltage ± __________ volts or ± ______________ %.

      Frequency ± __________ Hz or ± ______________ %.

   c. Stand-by requirements __________ kVA at __________ Hz, __________ phase, __________ volts at a power factor of __________

   d. On the basis of circuit needs to be satisfied by the earth terminal, indicate the power supply reliability required.

      ____

      ____

   e. Frequency converter required (AN/TSC-54 only).

      ( ) Yes ( ) No ( ) Not applicable

   f. Local power company contact ______________________________

      ____

7. Physical Survivability of Existing Structures.

a. Indicate commands and activities to be served by the earth station and degree of survivability of existing headquarters, command post, operations center, communications center, and similar activity associated with each.

Command or other Activity	Installation (e.g., Hq, CP, CommCen)	Degree of Hardness (psi)	Survivability Fallout Protection (days/hours)
____________	________________	____________	________________
____________	________________	____________	________________
____________	________________	____________	________________

b. Indicate distances between earth station and primary targets.

Primary Target	Approximate Distance (miles)
______________	________________________
______________	________________________
______________	________________________

8. Access Requirements.

a. The site selection data will include information about existing means of transmission that are available for establishing interconnect links from the earth terminal to a naval communications station facility. Some of the data to be included in paragraph 8 of the site survey data form (Appendix B) may be available during the presurvey planning.

b. Complete paragraph 8 of the site survey data form to the extent that information is available prior to survey and verify it during the survey.

9. Support.

The extent of the support required by the earth terminal will depend on the facilities which will have to be provided on-site as opposed to those which can be provided off-site by nearby military installation.

a. Personnel.

(1) Total station complement for operation and maintenance

____

(2) Number of personnel required for construction and installation

____

(3) Approximate length of time required for construction and installation

____

b. Storage.

(1) AN/MSC-46 Terminal. A spare parts kit provided with the terminal has about 2900 line items which are estimated to be about a year's supply. The maintenance van has sufficient storage space to accommodate the spare parts. In addition, about 70 percent of the inside of the cargo van is available for storage after it is unloaded at the site.

(2) AN/TSC-54 Terminal. A spare parts kit provided with the terminal consists of approximately 600 line items estimated to be about a year's supply. The shelter does not provide storage space for spare parts. The manufacturer's specifications state that storage facilities must be provided to store components of the equipment, spare parts, tools, instruction books and all other items that must be transported and used with the equipment.

(3) Factors. The storage space required for a particular earth terminal will depend upon its distance from the logistics support base and the number and types of terminals. Based on a consideration of these factors, requirements for storage space will have to be determined on an individual basis.

(4) POL Storage. Fuel consumption per diesel engine with the AN/TSC-54 terminal is approximately 5 gallons per hour. The fuel consumption per engine with the AN/MSC-46 is 8 gallons per hour. Two generators are required to supply the normal load of the AN/MSC-46. The storage requirements will depend on reliability of local power and POL sources, and will have to be determined on an individual basis. Indicate the required POL storage (a minimum of one week's supply):

(a) Bulk (gal.) ____________________

(b) Drum (sq. ft.) ____________________

(5) Vehicles.

(a) Type and number of vehicles required for installation ____________________

____

(b) Type and number of vehicles required for station operation ____________________

____

(c) Special cranes or hoists required (specify) ____________________

____

____

10. Other Pertinent Data. ____________________

____

____

APPENDIX B

SITE SURVEY DATA

1. Administrative Data

   a. This report reflects the results of a field site survey for ____________________
   facility located at ____
   ____
   This survey was conducted on (dates) ____________________________________

   b. Authority for this survey ____
   ____ dated ______________

   c. Composition of survey team:

NAME	TITLE	ORGANIZATION
____________	____________	____________
____________	____________	____________
____________	____________	____________
____________	____________	____________

   d. Key local military and civilian personnel contacted:

NAME	TITLE	ORGANIZATION
____________	____________	____________
____________	____________	____________
____________	____________	____________

2. Topography: A plan of the earth terminal site is provided as ____________________
____

3. Horizon Profile Data
   Location ____
   Site marker coordinates: Latitude ______________ Longitude ______________
   Date ____________ Temperature ______________ Visibility ______________
   Elevation of ground at instrument ________________________________
   Height of instrument above ground ________________________________
   Horizon profile plot shown on ________________________________

4. Photographs of Site and Horizon are attached (available from) ______________
____

5. Possible Radio Interference
   a. Radio or radar transmitters
      (1) Distance ______________________ miles.
      (2) Direction (azimuth) ______________________ degrees.
      (3) Frequency ____________ Pulse Rep. Rate (Radar) ____________
      (4) Type of emission ______________________
      (5) Power ______________________
   b. Radio receiving stations
      (1) Distance ______________________
      (2) Direction (azimuth) ______________________ degrees.
      (3) Receiving frequencies ______________________
      ____
      (4) Receiver sensitivity (or type and model) ______________________
      ____
      (5) Type of station or operating organization ______________________
      ____
   c. Azimuth and distance to railroads or highways ______________________
   ____
   d. Distance from power lines ______________________
   e. Distance from ordnance areas ______________________
   f. Distance to airways ______________________
      (1) Existence of airways or traffic patterns within sector of satellite visibility
      ____
      (2) Type of aircraft:
         (a) Preponderantly jet ______________________
         (b) Preponderantly propeller ______________________
         (c) Commercial airline ______________________
         (d) Private, light plane ______________________
   g. Anticipated industrial noise level ______________________
      (1) Distance ______________________
      (2) Direction ______________________ degrees.
      (3) Frequency ______________________
      (4) Power ______________________

6. Existing Power
   a. Capacity available ____________________
   b. Voltage __________ Frequency __________ Phase __________
   c. Distance to closest connection ____________________
   d. Construction required ____________________
   e. Remarks and pertinent data ____________________

   ____

7. Physical Security of Site
   a. Adequate (describe) ____________________
   b. Inadequate (list steps necessary to make adequate; fence, lights, guards, etc.)

   ____

8. Access to Naval Communications Station
   a. Communication requirements
      (1) Number of lines or voice channels ____________________

      ____

      (2) Quality required ____________________
   b. Interconnect links (see attached maps) ____________________
      (1) Link route, distance to, and locations of terminal facilities from the earth terminal ____________________

      ____

      ____

      (2) Number of channels:
         (a) Voice channels ____________________
         (b) Teletype channels __________ WPM __________
         (c) Data channels __________ BPS __________
      (3) Applicable transmission standards ____________________
      (4) Type of existing interconnect links ____________________
         (a) Open wire ____________________
         (b) Aerial/buried cable ____________________

Number pairs available __________ wire gauge __________

         (c) Troposcatter link __________ Frequency __________
         (d) Microwave LOS link __________ Frequency __________

9. Support

a. Personnel

(1) Off-base and on-base housing available

(2) Off-base and on-base messing facilities

(3) Administrative services for station personnel

10. Weather Data

a. Temperature: Max. Min. Average

b. Humidity: Max. , Average

c. Rainfall (inches) Max recorded Date: , 19

d. Snowfall (inches) Max recorded Date: , 19

e. Wind velocity (mph) Max. Direction

f. Presence of permafrost: Yes No

g. Maximum depth of frost line feet.

h. Unusual weather phenomena (hurricane, monsoon, sandstorm, etc.)

11. Real Estate

a. Ownership of site and access road area

b. Encroachment control required

c. Relocation of existing facilities required

d. Expansion capabilities

e. Requirements for host-tenant agreement

f. Zoning restrictions

g. Local government restrictions

12. Fence Enclosures

a. Area enclosed

b. Owner

c. Type and heights

d. Shown on drawing No.

13. Soil Bearing and Drainage

a. Bearing value ____________________

b. Type foundation required (drawing) ____________________

____

c. Drainage (describe) ____________________

____

14. On-Site Projections or Obstructions

____

____

15. Site Accessibility

a. Obstructions along access road (12 foot crown width)

(1) Overpass, tunnels: Location ____________________

Dimensions: Width ____________ Height ____________

(2) Bridges: Location ____________________

Maximum load capacity ____________________ pounds.

(3) Others: ____________________

b. Road improvement or temporary bridges needed ____________________

____

16. Frequency Clearance

Actions required to obtain frequency clearance ____________________

____

17. Remarks

____

____

____

____

APPENDIX C

REFERENCES

1. DCAC 370-185-1, DCS Applications Engineering Manual, Vol. 1, May, 1968.

2. DCAC 800-2000.1, Criteria for Earth Station Site Selection of the Defense Satellite Communications System (DSCS), May, 1968.

3. DCAC C810-2300.2 (Conf), Initial Defense Communications Satellite Project Earth Station/Defense Communications System Interface and Engineering Criteria (U), June, 1965.

4. DCA Report R-242102-1-2(b) (Conf), Defense Satellite Communication System — Description and Capabilities, June 1967.

5. Hdqtrs. U.S. Army STRATCOM, CCP 105-5, Introduction to Satellite Communications, Feb., 1968.

6. Technical Manual, Transportable Satellite Communications Link Terminal AN/MSC-46; Vol. I - Operators Information; Vol. II - System Installation, Alignment, Adjustment and Maintenance.

7. Technical Manual, Satellite Communication Terminal AN/TSC-54; Vol. 12 - Operator and Organizational Maintenance Manual, POMM 11-5895-389-12, Aug., 1968.

8. DCAC 300-175-1 (Conf), DCA RED/BLACK Engineering Installation Criteria (U), 19 Oct. 1964.

9. NAVELEXINST 011120.1 (Conf), Shore Electronics Engineering Installation Guidance for Equipments and Systems Processing Classified Information, 28 March 1968.

10. NAVORD OP 3565/NAVAIR 16-1-529 (Conf), Technical Manual Radio Frequency Hazards to Ordnance, Personnel, and Fuel, Revision 3 of 15 August 1969 with effective changes.

11. University of California Engineering and Sciences Extension Series, Space Communications, edited by A. V. Balakrishnan, McGraw-Hill Book Co., Inc., 1963.

12. Schwartz, J. W.; Aien, J. M.; and Kaiser, J. "Modulation Techniques for Multiple Access to a Hard Limiting Satellite Repeater," Proceedings of IEEE, May 1966, 763-777.

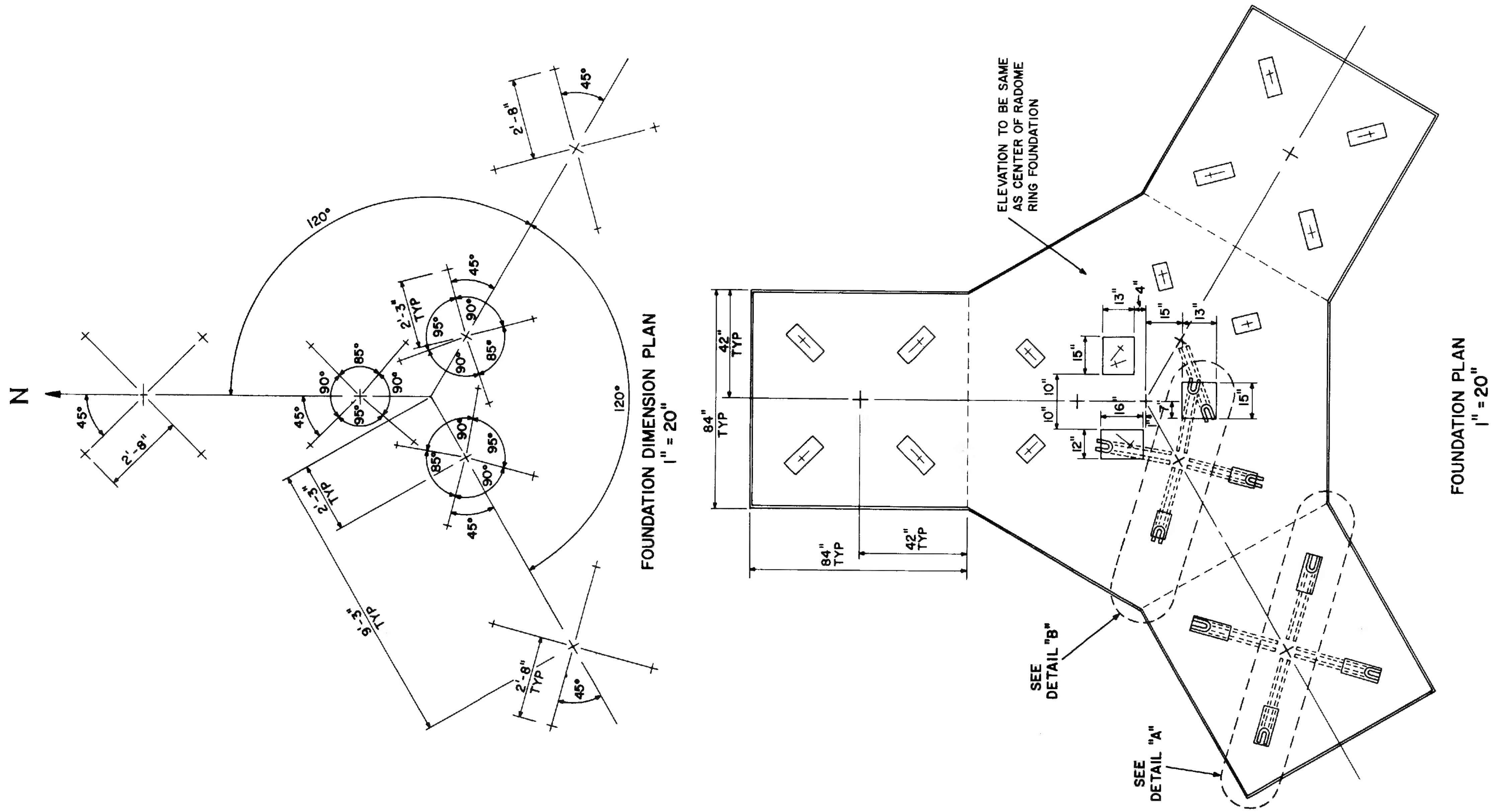
13. Clarke, Arthur C. "Extra-Terrestrial Relays," Wireless World, October, 1945.

14. Cohen, Jay J. "Military Services Satellites Will Ring the Earth," Electronics, May 2, 1966, 96-99.

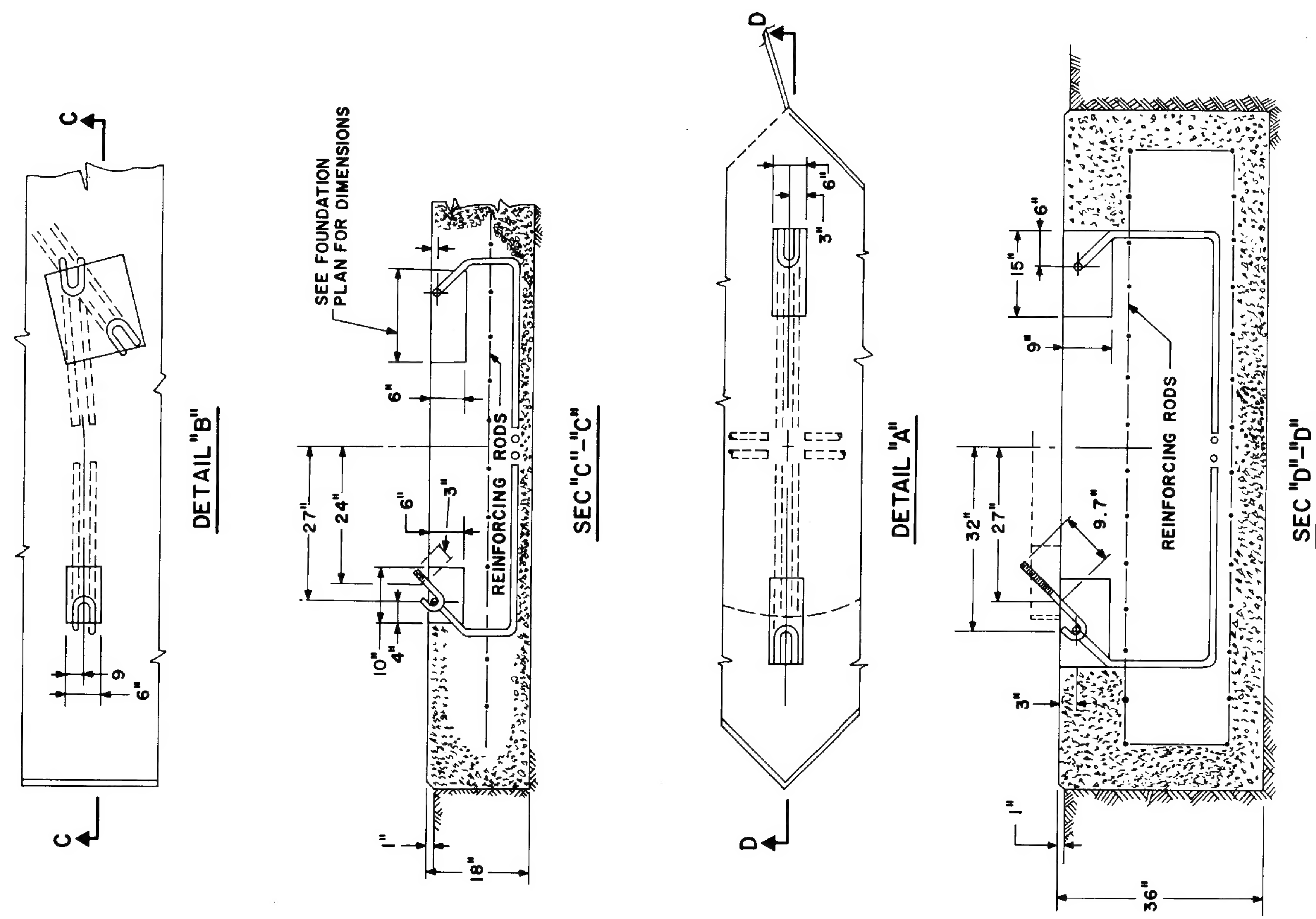
15. TRW Space Log - Winter 1968-1969.

16. EASCON '69 Convention Record, IEEE Transactions on Aerospace and Electronic Systems, October, 1969.

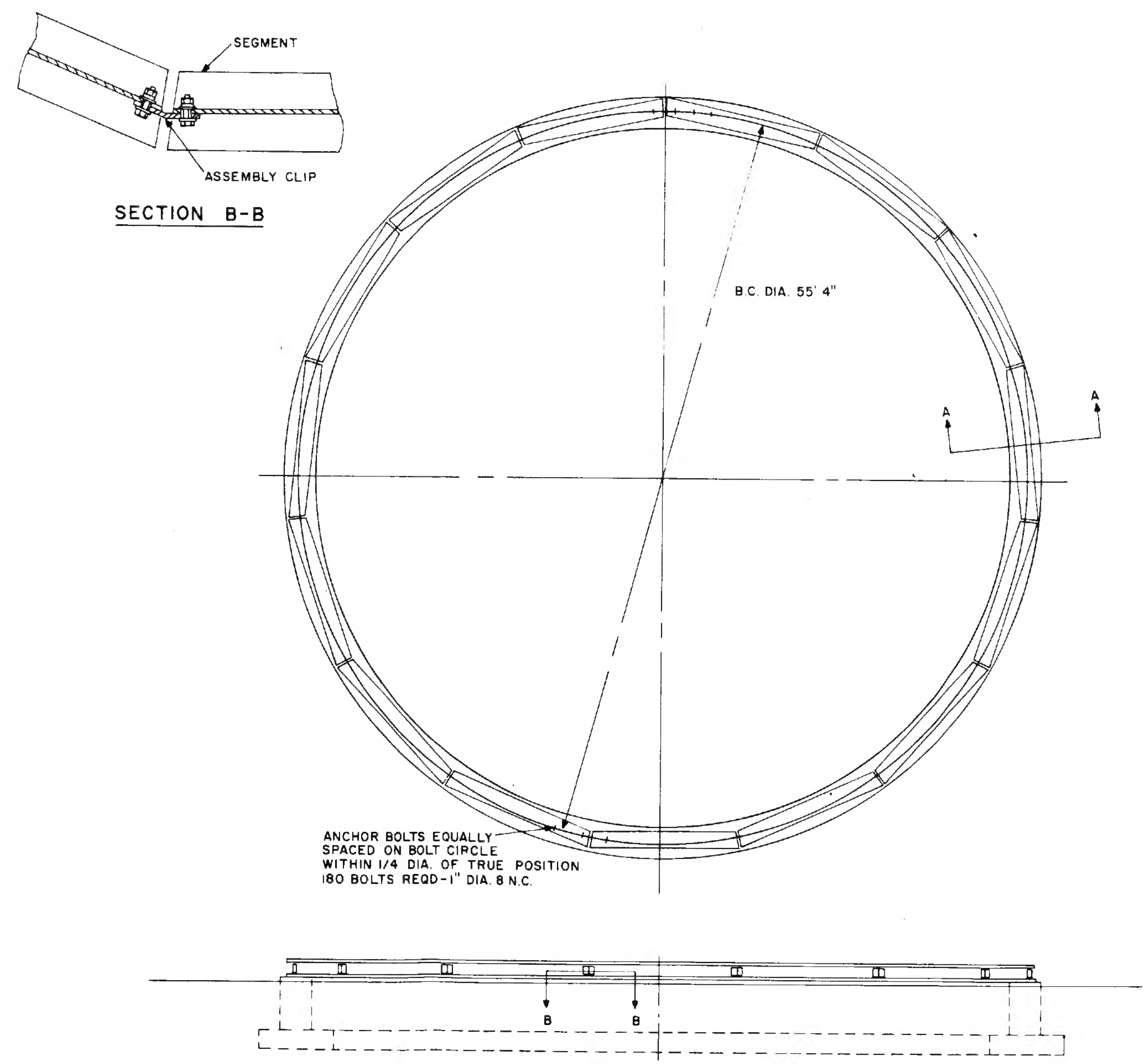
☆ U. S. GOVERNMENT PRINTING OFFICE : 1971 O - 422-671

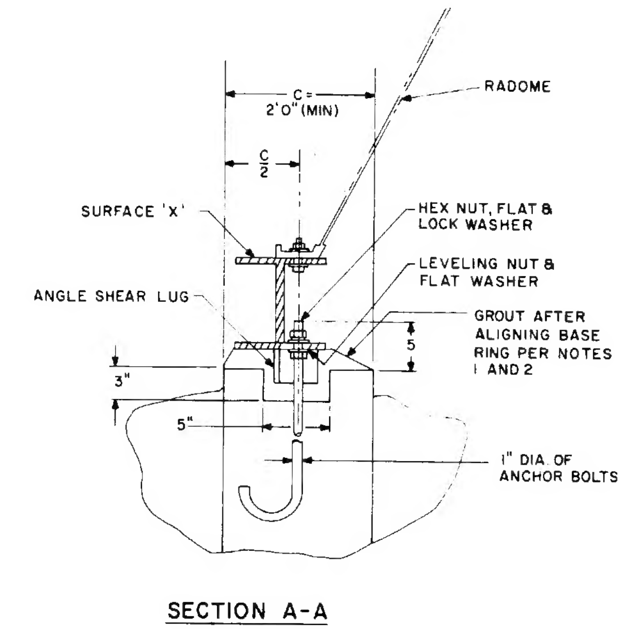


Foldout 3-1. Typical Foundation for
AN/MSC-46 Antenna Pedestal
(Sheet 1 of 2)



Foldout 3-1. Typical Foundation for AN/MSC-46 Antenna Pedestal (Sheet 2 of 2)





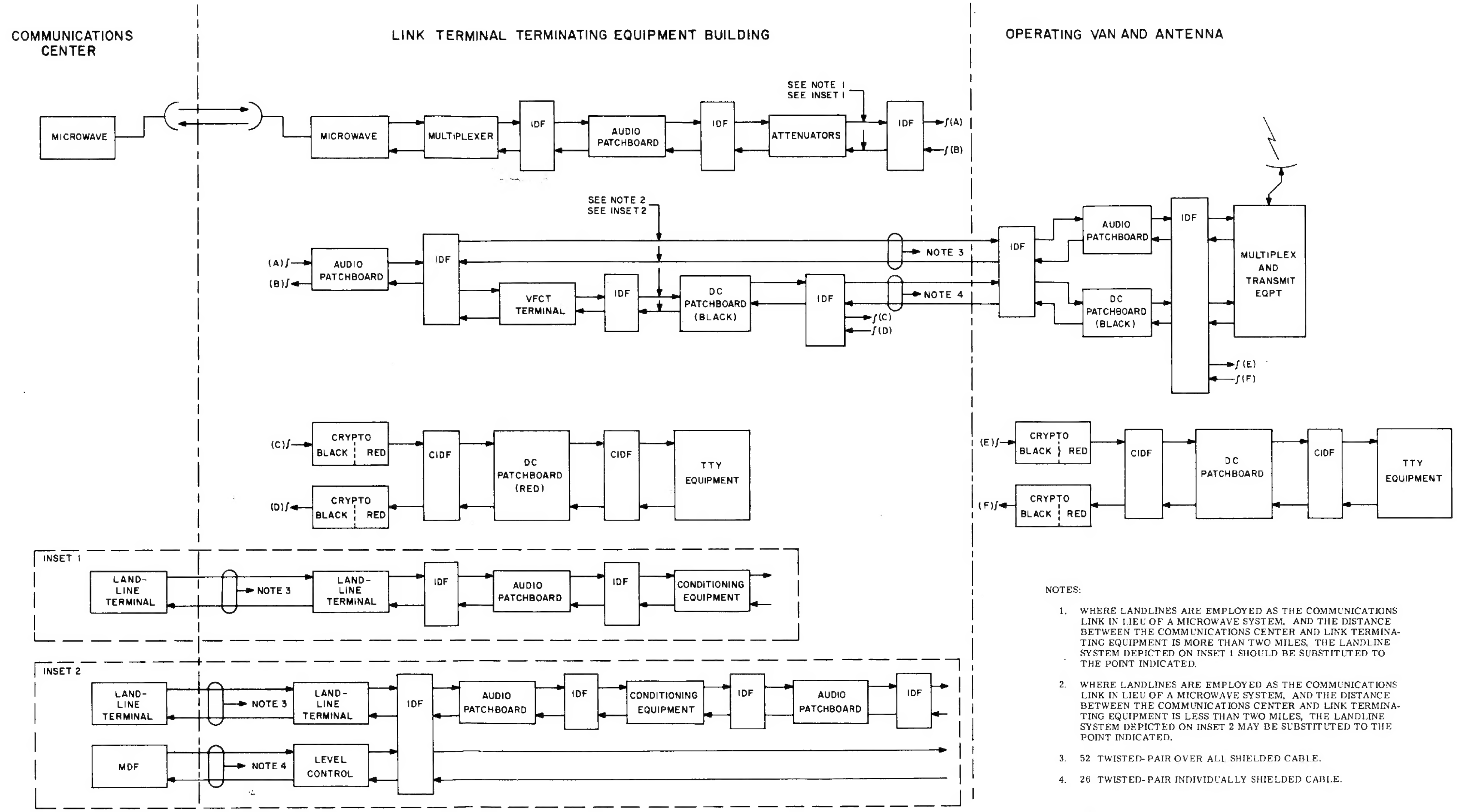
NOTES:

1. BASE RING SEGMENTS ARE TO BE ALIGNED RADIALLY SO THAT THE RADOME MOUNTING HOLES ON SURFACE 'X' ARE LOCATED WITHIN 1/6 OF TRUE POSITION, ALIGNMENT TOOLS ARE SUPPLIED WITH BASE

2. ENTIRE RADOME MOUNTING SURFACE 'X' IS TO BE LEVEL WITHIN 1/8", EACH BASE SEGMENT IS TO BE LEVEL WITHIN 1/32"

3. RADOME DIAMETER- 68'0", DRAG-113,000 LBS., LIFT-254,000 LBS.; OVERTURN MOMENT-2,200,000 LBS., RADOME WEIGHT-20,000 LBS., WIND VELOCITY-155 KNOTS.

Foldout 3-2. Typical Foundation for Radome for AN/MSC-46 Antenna



NOTES:

1. WHERE LANDLINES ARE EMPLOYED AS THE COMMUNICATIONS LINK IN LIEU OF A MICROWAVE SYSTEM, AND THE DISTANCE BETWEEN THE COMMUNICATIONS CENTER AND LINK TERMINATING EQUIPMENT IS MORE THAN TWO MILES, THE LANDLINE SYSTEM DEPICTED ON INSET 1 SHOULD BE SUBSTITUTED TO THE POINT INDICATED.

2. WHERE LANDLINES ARE EMPLOYED AS THE COMMUNICATIONS LINK IN LIEU OF A MICROWAVE SYSTEM, AND THE DISTANCE BETWEEN THE COMMUNICATIONS CENTER AND LINK TERMINATING EQUIPMENT IS LESS THAN TWO MILES, THE LANDLINE SYSTEM DEPICTED ON INSET 2 MAY BE SUBSTITUTED TO THE POINT INDICATED.

3. 52 TWISTED-PAIR OVER ALL SHIELDED CABLE.

4. 26 TWISTED-PAIR INDIVIDUALLY SHIELDED CABLE.

Foldout 3-3. Typical Earth Terminal Circuit Distribution